A.R.C.

INDUSTRIES LIMITED

A.R.C. REINFORCEMENTS

W. ABERNETHY

A.R.C.
REINFORCEMENTS

by

A. R. C. ENGINEERING CO. PTY. LTD.

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PREFACE

THIS Handbook has been compiled to bring to your notice the advantages to be derived from the use of A.R.C. Reinforcements.

We have included tables and data generally which are of use to all interested in Reinforced Concrete Construction.

Our works at Albion, Victoria, Homebush, New South Wales, and Brompton, South Australia, are well equipped for the manufacture and fabrication of our reinforcements.

All enquiries will receive prompt attention.

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REINFORCED CONCRETE AND A.R.C. REINFORCMENTS

The first edition of our handbook was produced 30 years ago, and since then much progress has been made in the technique of design and construction of reinforced concrete, and its uses have been widely extended.

Reinforced concrete has replaced the older materials, masonry, timber, brickwork, mass concrete and constructional steel work, to an ever-increasing extent, and has proved its economy and durability over many years.

The training of every engineer, architect and builder now includes a study of at least the fundamentals of the theory and practice of reinforced concrete, and it is not necessary in a book of this nature to discuss the elementary principles, which are, in any case, best learnt from a standard textbook.

A.R.C. REINFORCEMENTS

A.R.C. reinforcements cover the whole range of reinforced concrete construction in a simple and complete manner by means of A.R.C. Fabric, and by A.R.C. Hoops, Helicals and Stirrups, in combination with steel bars and other sections.

The name "A.R.C." is well known in the building and civil engineering industry, and immediately suggests hard-drawn mild steel wire mesh fabric, of which large quantities have been manufactured here and abroad, for use in the construction of floors, walls, roads, etc., and for many other uses beyond its original sphere in reinforced concrete.

In addition to being the manufacturers of A.R.C. fabric, we carry large stocks of mild steel bars for reinforcing purposes.

A.R.C. FABRIC

In the earliest constructions of reinforced concrete, mild steel bars were generally used for reinforcement. The

arrangement of bars in slabs was usually very complicated because a large number of bars had to be laid, spaced out, wired together and maintained in position during concreting. A.R.C. fabric was introduced to overcome this difficulty. It consists of an oblong or square mesh of steel wire supplied in sheets or rolls, equivalent to numerous loose bars that have to be wired together at the site. The greater portion of the spacing and fixing has been done before the material leaves our works, thereby reducing the amount of labor and supervision required on the site.

A.R.C. fabric is made from high-grade, hard-drawn mild steel wire, complying with British Standard 785. The main wires of the fabric are held rigidly at the correct spacing by cross wires electrically welded to them.

A.S. No. A82
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Yield Stress 70,000 p.s.i.

A.R.C. HOOPS AND HELICALS

A reinforced concrete column, square, oblong or circular in section, or other shape to suit the purposes of the designer, is reinforced with vertical mild steel bars spaced evenly around the perimeter. It is necessary to maintain these bars in their exact position during concreting so as to maintain the requisite cover, and, at the same time, to ensure that the free ends of the bars shall be in their correct position to enable the bars in the beams over to pass through in accordance with the designer's details.

A.R.C. hoops and helicals for this purpose are machine-made with a high degree of accuracy.

A.R.C. STIRRUPS

In all reinforced concrete beams, proper provision must be made to resist shearing stresses, or more accurately, the diagonal tensile stresses which are set up as a result of shearing action.

The shear reinforcement in ordinary reinforced concrete beams generally consists of a combination of bars bent up from the bottom of the beam, and rectangular stirrups or ligatures passing around the perimeter of the beam cross section.

Like A.R.C. hoops and helicals, A.R.C. stirrups are machine-made with similar accuracy. Hoops, Helicals and Stirrups are generally referred to under the comprehensive title of "Fitments".

APPLICATIONS OF A.R.C. REINFORCEMENTS

The uses to which A.R.C. reinforcements may be applied with advantage, comprise almost any purpose where a load is to be carried, material contained, or where a surface is required to be fire-resisting or waterproof, such as:

Foundations	Partitions	Tanks
Piles	Staircases	Culverts
Columns	Bins and Bunkers	Sewers
Beams	Silos	Retaining Walls
Slabs	Bridges	Dock Walls
Roofs and Floors	Reservoirs	Wharves
Lintels	Colliery Structures	Encasing Steelwork
Walls	Chimneys	Roads

A.R.C.
DESIGN AND SERVICE

ENGINEERING DEPARTMENT

Although the design of reinforced concrete structures is based on well-known principles common to all kinds of structural engineering, there is a great deal of complication in connection with details, which can be dealt with only by designers who are engaged continually on this class of work, and are acquiring increased knowledge as a result of experience. It is for this reason that there exists, and will continue to exist, the profession of the designer of reinforced concrete structures, and only such designers are competent to do the work efficiently.

We employ a technical staff of proved ability and experience, and are prepared to submit schemes and designs for all classes of reinforced concrete work.

PREPARATIONS OF DESIGNS

The particulars of a client's requirements for any enquiry having been obtained, our normal procedure for large jobs is to put the scheme in hand in our drawing office, and to develop it to such a stage that contractor's tenders may be obtained.

This generally involves the preparation of drawings showing the sizes of the various concrete members, together with any necessary layout dimensions and notes.

A quotation is then forwarded to the client giving a lump sum for the design and the supply of the necessary reinforcements, or the amount of our charge if arranged on a "fee" basis.

WORKING DETAILS

The preliminary scheme having been approved and accepted, we then proceed with the preparation of our working detail drawings. These give full particulars of the reinforcement and its exact location in the structure.

Our method of detailing has been developed over a long period, and our drawings are favourably received by those who have to work from them at the site.

SUPPLY OF REINFORCEMENTS

The supply of reinforcements by us is the essential part of our business. We are the actual manufacturers of A.R.C. fabric, and normally hold stocks of every standard size. A considerable proportion of the total weight of reinforcements usually consists of mild steel bars. We are in constant touch with the rolling mills, and being regular purchasers, are generally in a position to obtain preferential service.

We carry stocks of bars of diameters and lengths generally used in reinforced concrete work, which enable us to supply material immediately.

We are prepared to submit quotations for the supply of any type of reinforcements, cut to length and bent to shape in accordance with a design and details submitted to us.

To meet these requirements, we have a large bending shop, equipped with the most modern type of power-driven bar cutters and benders, and can handle large or small orders expeditiously.

ARCHITECTURAL WORK

Our business is limited to the design of reinforced concrete and the manufacture and supply of reinforcements, and we do not, in any circumstances, carry out any architectural work except under instruction from practising architects.

SUBMITTING AN INQUIRY

Adequate information is necessary to produce the best design, particularly when communicating by correspondence.

The essential particulars for various types of structures are as follows:—

FLOORS ON GROUND

1. Nature of loading on the slab.
2. Is the slab on solid or excavated ground, or on filling?
3. If on filling, what is the depth and nature of the filling?
4. If carrying machine loads, the weight and description of the machines.

SUSPENDED FLOORS

1. Plans required showing layout of all supports (beams, walls or columns). Sufficient sections to show changes in floor levels.
2. Are the beams to be in reinforced concrete or structural steel R.S.J.'s?
3. If the latter, are they encased or not, and the depth of top of R.S.J. below top of floor slab?
4. Is there any restriction on the depth of beams?
5. What is the nature of the floor finish? If timber, will timber battens be embedded to fix the timber flooring? Will they run the short way of slab or the long way?
6. For what purpose is the floor required and/or the loading on floor?
7. Any additional particulars regarding concentrated or special loads on the floors.
   It may be desirable to describe the merchandise or machinery to be carried.

FRAMED BUILDINGS

1. Plans, sections, and elevations required. Position of boundaries and adjoining buildings.
2. Data for floors as for suspended floors.
3. Nature of ground, and if known, its bearing capacity.
4. At what depth is a good foundation obtained?
5. What is the level (winter and summer) of standing ground water?
6. Roof finish required?
7. Is a layout required giving the least number of columns? Generally, for factories and warehouses, the fewer the columns the greater the cost.
   If the most economical layout is required, this should be stated.
8. Is any special arrangement of beams necessary for ceiling effect?

TANKS

1. Internal dimensions and depth of water.
2. Capacity in gallons.
3. Is it to be underground, part in the ground, or on the ground?
4. If above ground, what is the nature of supports proposed?
5. Nature of the ground.
6. Is a concrete roof required, and if so, will there be any loads on the roof?

RETAINING WALLS

1. Site plan showing levels of site, and sections.
2. What is the nature of foundation material, and the earth to be retained?
3. If known, the bearing capacity of the ground?
4. Is there any objection to a heel at the back of the wall? It is undesirable to have the base slab wholly in front.
5. Is the retained earth liable to surcharge from traffic or adjoining buildings?
6. What is the extent of water seepage from the bank to be retained.

MATERIALS USED IN REINFORCED CONCRETE

STEEL BARS

The steel bars used in reinforced concrete construction are usually in the form of plain round sections, but the deformed bar is now widely used in U.S.A. and some other overseas countries. By means of the projections or depressions on its surface, this type of bar provides a definite increase in bond strength over plain bars.

The diameters in common use vary from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in. in steps of $\frac{1}{8}$ in. It is only in exceptionally heavy work and in very large members that bars larger than $1\frac{1}{4}$ in. diameter are adopted.

Steel for use as concrete reinforcement is covered by British Standard 785. This specification schedules four qualities of steel — mild steel, medium tensile steel, high tensile steel, and hard drawn steel wire. Practically all the reinforcement used in reinforcing concrete work is rolled from mild steel or manufactured from hard drawn steel wire. The ultimate tensile strength specified for mild steel is 28 to 33 tons per square inch, with elongations, on gauge lengths of not less than 8 times the diameter, of 20 per cent. for bars up to 1 in. diameter, and 16 per cent. for bars under $\frac{3}{8}$ in. diameter. For bars over 1 in. diameter, the elongation is 24 per cent. on a gauge length of not less than four times the diameter. The bars must also stand a cold bend test without fracture by doubling over the test piece until the two sides are parallel, with an internal radius of bend not greater than the diameter of the test piece for bars up to 1 in. diameter, and $1\frac{1}{2}$ times the diameter of the test piece for bars over 1 in. diameter. It is recommended that rolled steel bars less than $\frac{3}{8}$ in. diameter should be avoided as far as practicable where it is important that the calculated area should be provided, because the cross-section is often irregular and liable to vary considerably. Drawn wire which is true to gauge is preferable.

The kinds of steel described above can be bent cold to any shape required for use in reinforced concrete work. It is neither necessary nor desirable to heat the bars to facilitate bending.

PROPERTIES OF ROUND AND SQUARE STEEL BARS

Diameter or side (in.)	ROUND BARS		SQUARE BARS	
	Area of cross-section (sq. in.)	Weight per foot length (lb.)	Area of cross-section (sq. in.)	Weight per foot length (lb.)
$\frac{1}{4}$	0.049	0.167	0.063	0.213
$\frac{5}{16}$	0.077	0.261	0.098	0.332
$\frac{3}{8}$	0.110	0.376	0.141	0.478
$\frac{7}{16}$	0.150	0.511	0.191	0.651
$\frac{1}{2}$	0.196	0.668	0.250	0.849
$\frac{9}{16}$	0.249	0.845	0.316	1.076
$\frac{5}{8}$	0.307	1.043	0.391	1.328
$\frac{11}{16}$	0.371	1.262	0.473	1.607
$\frac{3}{4}$	0.442	1.502	0.563	1.912
$\frac{13}{16}$	0.519	1.763	0.660	2.245
$\frac{7}{8}$	0.601	2.044	0.766	2.603
$\frac{15}{16}$	0.690	2.347	0.879	2.988
1	0.785	2.670	1.000	3.400
$1\frac{1}{8}$	0.994	3.380	1.266	4.303
$1\frac{1}{4}$	1.227	4.172	1.563	5.312
$1\frac{3}{8}$	1.485	5.049	1.891	6.428
$1\frac{1}{2}$	1.767	6.008	2.250	7.650

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DRAWN STEEL WIRE

The reinforcing wire used in A.R.C. Fabric is in accordance with B.S. No. 785. The specification calls for an ultimate tensile strength from 37 to 42 tons per square inch, an elongation of $7\frac{1}{2}$ per cent. on a gauge length not less than 8 times the diameter, and a cold bend of 90 degrees, then back through 180 degrees and then to original position.

The chemical analysis of the wire is exactly the same as that of rolled mild steel, and drawn wire is still mild steel. The difference is that whilst rolled rods are simply rolled to shape, drawn steel wire is rolled first and then drawn. This process does not alter the chemical analysis or the modulus of elasticity, but it does greatly increase the breaking strength and, what is more important, it raises the yield point by about 100 per cent. For this reason alone, drawn steel is a much superior reinforcement where practical sizes permit its use, i.e. in floor slabs and similar large areas of concrete.

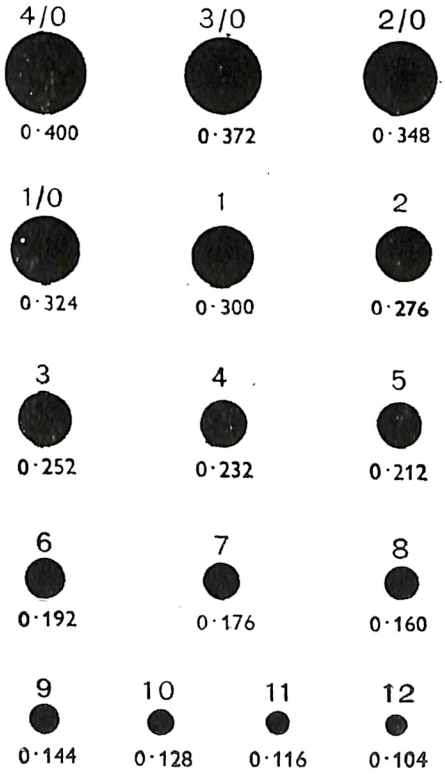
There are one or two other points worthy of notice in comparing drawn and rolled steel. The process of drawing the steel is in itself a test of quality, by bringing to light any defect in the material. It also ensures uniformity of cross-section, whereas the diameter of a rolled steel section may vary appreciably. As A.R.C. Fabric is used in cases where it replaces small diameter rolled rods, it ensures accuracy in sectional area in just the cases where rolled steel may be most inaccurate.

METRIC EQUIVALENT OF STANDARD WIRE GAUGES

Standard wire gauge	Diam. in millimetres	Standard wire gauge	Diam. in millimetres	Standard wire gauge	Diam. in millimetres
4/0	10.16	3	6.40	9	3.66
3/0	9.45	4	5.89	10	3.25
2/0	8.84	5	5.39	11	2.95
1/0	8.23	6	4.88	12	2.64
1	7.62	7	4.47	13	2.34
2	7.01	8	4.06	14	2.03

FULL SIZE SECTIONS OF WIRES

Diameters stated in Standard Wire Gauges
and decimals of an inch



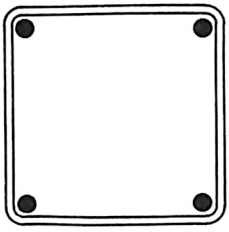
A.S. No. A82
Min. U.T.S. 80,000 p. s. i.
Yield Stress 70 000 p. s. i.

PROPERTIES OF A.R.C. STEEL WIRE

Tensile Strength:
Minimum 83,000 lb. per sq. in. (= 37 tons per sq. in.)

Standard wire gauge	Diam. (in.)	Area of cross-section (sq.in.)	Weight per 100 ft. (lb.)	Minimum tensile strength (breaking) (lb.)	Area of cross-section (sq. in.) per ft. width if wires are spaced at			
					2 in. cent.	3 in. cent.	4 in. cent.	6 in. cent.
4/0	0.400	0.1257	42.73	10430	0.7540	0.5027	0.3770	0.2513
3/0	0.372	0.1087	36.95	9021	0.6521	0.4347	0.3261	0.2174
2/0	0.348	0.0951	32.34	7895	0.5707	0.3805	0.2853	0.1902
1/0	0.324	0.0824	28.03	6843	0.4947	0.3298	0.2473	0.1649
1	0.300	0.0707	24.03	5867	0.4241	0.2827	0.2121	0.1414
2	0.276	0.0593	20.34	4966	0.3590	0.2393	0.1795	0.1197
3	0.252	0.0499	16.96	4140	0.2993	0.1995	0.1496	0.0998
4	0.232	0.0423	14.37	3509	0.2536	0.1691	0.1268	0.0845
5	0.212	0.0353	12.00	2930	0.2118	0.1412	0.1059	0.0706
6	0.192	0.0290	9.84	2403	0.1737	0.1158	0.0869	0.0579
7	0.176	0.0243	8.27	2019	0.1460	0.0973	0.0730	0.0487
8	0.160	0.0201	6.84	1669	0.1206	0.0804	0.0603	0.0402
9	0.144	0.0163	5.54	1352	0.0977	0.0651	0.0489	0.0326
10	0.128	0.0129	4.38	1068	0.0772	0.0515	0.0386	0.0257
11	0.116	0.0106	3.59	877	0.0634	0.0423	0.0317	0.0211
12	0.104	0.0085	2.89	705	0.0510	0.0340	0.0255	0.0170

A.R.C. HOOPS AND HELICALS



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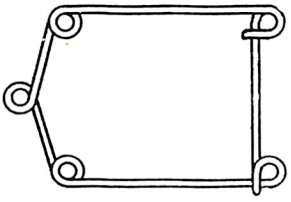

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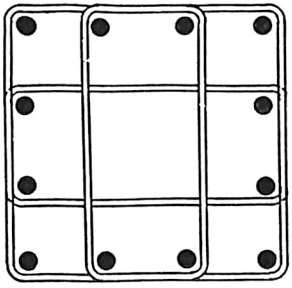

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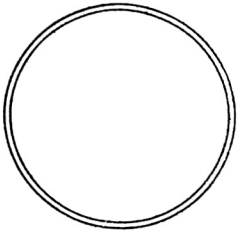

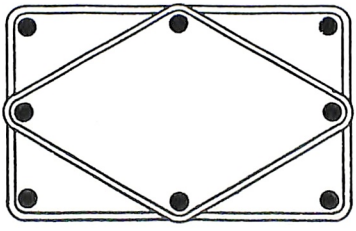

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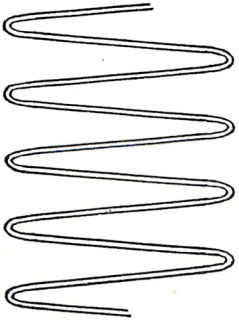

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Fig. 1.

A.R.C. FITMENTS

HOOPS (Fig. 1)

No. 1 is a hoop for square columns, piles and the like. The shape is designed to enclose four or more bars. A similar type is used for rectangular columns with sides of unequal length.

No. 2 is an arrangement of hoops to suit a square — or rectangular — column having twelve bars. A large hoop, which encloses all the bars and keeps them in position to the desired over-all size of unit, is used in conjunction with a pair of smaller rectangular hoops placed at right angles to each other, each of the latter dimensioned to enclose four bars, two on each opposite side.

A similar arrangement can also be used for square or rectangular columns having eight or ten bars.

No. 3 is an alternative arrangement for a rectangular or square column having eight bars.

No. 4 shows a special type to hoop 5 bars. The loops are set back on one side and set forward on the other, to allow for encircling the bars in a section such as a sheet pile, having a projection or tongue on one side and a groove on the other. Hoops can be made for any special shape or arrangement of bars.

HELICAL WRAPPINGS

No. 5 is a circular helical used for either circular or octagonal columns and piles. It may also be used for square columns designed as spirally reinforced columns. The diameter of wire used and the pitch of the helical is determined by the load which the column has to carry. They are usually made from cold drawn steel wire.

A.R.C. STIRRUPS (Fig. 2)

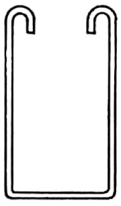
No. 1 is a standard type two-leg stirrup for a rectangular beam, although it may also be used for T beams.

No. 2 is for T beams monolithic with a slab. The ears rest on the slab form-work as in 3, and are dimensioned to support the bottom bars in the beam with the correct cover, and at the same time afford support to the slab negative reinforcement if such is required. In such a case, a $\frac{3}{8}$ in. diameter continuous rod is usually wired to the ears of the stirrups as shown in 3.

No. 4 is a similar stirrup for an L beam with a slab on one side only.

All types of stirrups may be manufactured with 4 legs, as in No. 5, or more if required, although it is usually more economical to use an equivalent 2-leg type in a larger diameter, up to the practical limit of about $\frac{5}{8}$ in. maximum diameter.

A.R.C STIRRUPS



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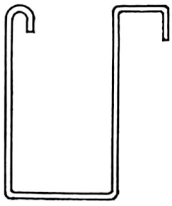

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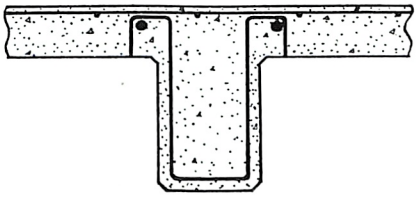

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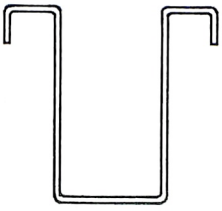

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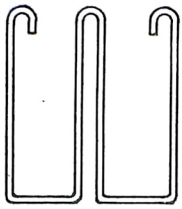

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Fig. 2.

A.R.C. FABRIC

MATERIAL AND MANUFACTURE

A.R.C. electrically cross-welded steel wire fabric is the ideal reinforcement for concrete slabs and surfaces. It consists, Fig. 3, of a wire mesh made up of a series of parallel longitudinal wires, held at fixed distances apart by means of transverse wires arranged at right angles to the longitudinal ones, and electrically welded to them at the points of contact.

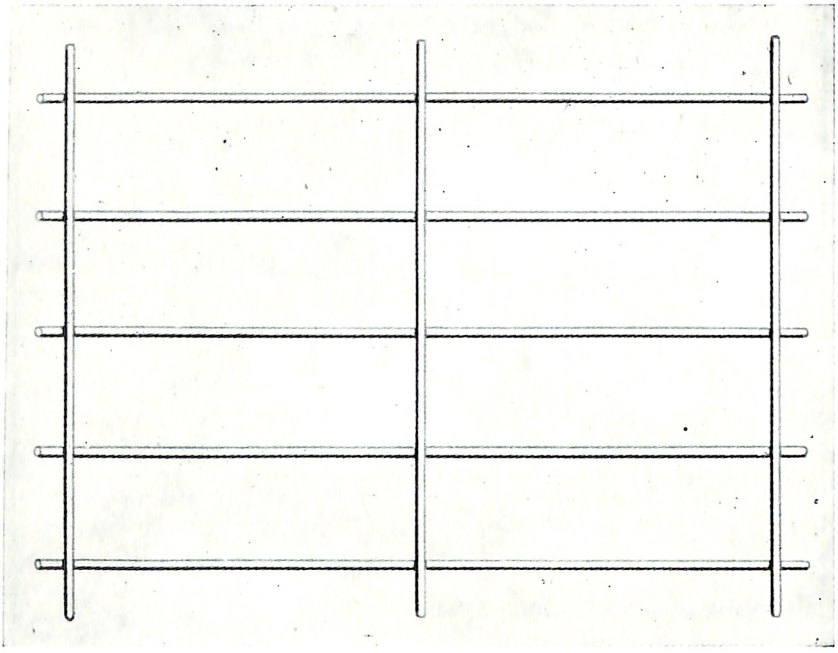


Fig. 3.

The longitudinal wires, which may be of any gauge, are automatically drawn from supply reels through a machine, which accurately spaces them at fixed distances apart. Progress of the longitudinal wires through the machine stops momentarily at definite intervals, whilst a single strand of transverse wire is placed across the longitudinal ones at right angles to their length. At each point where the transverse wire crosses the longitudinals, there is an electrical contact which welds the two wires together.

The appearance of the finished product is illustrated in the accompanying photograph, Fig. 4, of a roll of A.R.C. Fabric. In this view the unrolled portion of the fabric clearly shows the perfect alignment of the wires, and the efficient manner in which they are held in their proper relative positions.

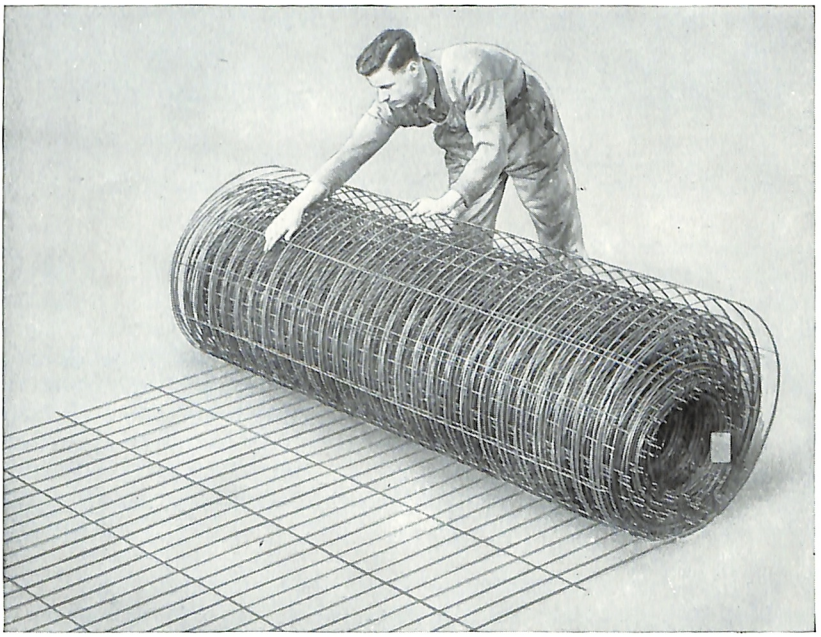


Fig. 4.

STRENGTH OF WELD

Each point of intersection between longitudinal and cross wires will develop one half of the full strength of the cross wire before the weld is sheared. This result connot be obtained by means of wire, loops or clips. Fig. 5 is a view of a piece of electrically cross-welded steel wire illustrating the character of the weld between the two wires; the two wires have been cut through at their point of union, revealing a perfectly smooth surface, in which it is impossible to detect the slightest evidence of separation between the wires.

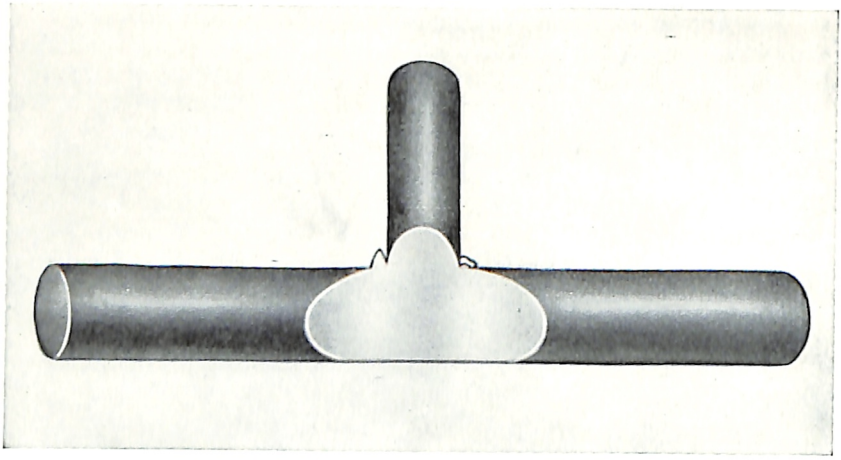


Fig. 5.

SPACING OF WIRES

Every strand of wire entering into the construction of A.R.C. Fabric is, through its process of manufacture, properly placed with mechanical accuracy. In this way machinery accomplishes an essential element of construction, which in other types of reinforcing material, is often left in the hands of unskilled workmen after it has reached its destination.

RIGIDITY

Modern practice has demonstrated the importance of rigidity in all types of reinforcement. A.R.C. Fabric provides the greatest possible rigidity, owing to its having an absolute physical connection at each point of intersection, thus overcoming the great defect of all systems of rod reinforcement. In these other systems, such absolute connection is non-existent.

CONTINUITY OF REINFORCEMENT

A.R.C. Fabric is laid in sheets or rolls up to 7 ft. 6in. in width and of any length up to 240 feet. There may thus be obtained an unbroken sheet of reinforcing material extending from end to end of the structure, providing a single continuous unit of drawn steel wire. One roll of A.R.C. Fabric is equivalent to numerous loose rods. The labour of handling it is less than one-tenth the labour of handling rods, and the supervision required for correct placing is only a fraction of the supervision required for separate rods.

DIRECT ACTION IN REINFORCEMENT

It is a well-established principle that any structure in sustaining certain loads is deformed by those loads in such a way that the total work done by the resisting stresses in the material is a minimum. The most efficient type of reinforcing material is the one capable of resisting all tensile stresses in the simplest and most direct manner. Both theoretical and practical demonstrations show the fallacy of statements to the effect that a zig zag, crimped, or any indirect line of reinforcement, when embedded in concrete, is as efficient as a direct line. A.R.C. Fabric reinforces efficiently on direct lines of tension, and maintains its original form when stressed.

EASE AND ACCURACY OF INSTALLATION

The most important, and in many cases the most difficult work in connection with the erection of reinforced concrete structures, is the accurate spacing of the steel. In order that a slab of concrete may safely sustain its superimposed load, it is not merely essential that it be provided with a certain amount of steel, but the greatest care must be taken to see that the steel is correctly placed in the concrete. Unless the reinforcement is in the same position in the actual structure as is shown on the drawing, the performance and safety of the structure is reduced. Carelessness in regard to this important feature may lead to failure in structures of reinforced concrete.

Where single rods are used, a considerable expenditure of time and money is involved, as it is necessary to lay the bars separately, carefully space them, and then to fasten them in position. The correctness or otherwise of such positions is completely dependent on the man — usually unskilled — who is actually laying the reinforcement. This risk is eliminated by using A.R.C. Fabric. It comes to the site in rolls or sheets and can be neatly stored in a small space until required, and when required, can be easily laid. The exact spacing of the wires is already established, and it is impossible for their relative positions to become changed in the slightest degree, either before or after laying, or during concreting.

FLEXIBILITY OF DESIGN

A.R.C. Fabric is not, like many other forms of reinforcement, an intricate system that admits of only restricted usage. It may be adapted to any type of construction, and in all cases provides

a simple and efficient means of continuous reinforcement. It is commonly used in the construction of foundations, walls, slabs, floors, roofs, bins, tanks, reservoirs, sewers, culverts, bridges, retaining walls, platforms, pavements, fire proofing of steel work, and flat or curved concrete surfaces of all kinds. On Pages 67 and 68 we give diagrams showing the application of our fabric to floors, whether carried by steel or reinforced concrete beams.

FACTOR OF SAFETY

In the design of structure, the working stresses are usually one-third to one-quarter of the nominal ultimate strengths, and this ratio is commonly referred to as the factor of safety. Its purpose is to make provision for any possible overloading of a temporary and unexpected nature which may occur during the lifetime of a building, and also to guard against defects and variations in materials and workmanship. It is important to recognize that when a structure is designed having a factor of safety of three, it does not mean that the loading could be increased to three times the designed loading without failure taking place. Failure begins as soon as the materials have passed their yield points and so become permanently deformed, and therefore the factor of safety should be based on this figure. For rolled mild steel bars, this would be at a stress of approximately half the ultimate or breaking strength, but for cold drawn steel wire as used in A.R.C. Fabric, it is nearer 85 per cent. of the ultimate strength.

Comparing a slab reinforced with A.R.C. Fabric with one reinforced with mild steel bars having the same calculated strength, the allowable working stress for the fabric is 27,000 lb. per sq. in. and that for the mild steel bars 18,000 lb. per sq. in. The yield point for fabric is approximately 70,000 lb. per sq. in., and that for mild steel probably 32,000 lb. per sq. in. and the

Real Factor of Safety is:

A.R.C. Fabric $\frac{70,000}{27,000} = 2.59$ Mild Steel Bars $\frac{32,000}{18,000} = 1.78$

Therefore, a slab reinforced with A.R.C. Fabric is considerably stronger than one reinforced with mild steel bars having the same nominal strength.

ECONOMY

It is obvious from the previous figures that the weight of A.R.C. Fabric is only eighteen-twenty-sevenths or approximately two-thirds of the weight of the equivalent mild steel bars.

In addition, the cost of laying the fabric in position is only a fraction of the cost of placing, spacing out, and fabricating mild steel bars on the job, and the labour and supervision on the site is reduced to a minimum.

A.R.C. FABRIC STANDARDS

The following particulars apply to our standard A.R.C. manufactures for reinforcement purposes. We can, however, supply almost any combination of wire to meet customers' requirements.

TYPE OF WIRE

Hard drawn steel wire to British Standard with a breaking strength of 83,000 lb. to 94,000 lb. per square inch, and a minimum yield point of 70,000 lb. per square inch.

This wire, in addition to being perfectly regular in cross section, is the same quality and strength from skin to core.

A.S. No. A82
Min. U.T.S. 80,000 p.s.i.
Yield Stress 70,000 p.s.i.

SIZE OF WIRE

We can furnish any size longitudinal wire from 4/0 to 10 gauge (inclusive) combined with any size transverse wire from 1 to 10 gauge inclusive, providing the difference between them does not exceed seven numbers of Imperial Standard Wire Gauge.

SPACING OF LONGITUDINAL WIRES

Longitudinal wires are spaced at centres of 3 in. and upwards in multiples of 3 in. Our standard spacings are 3 in. and 6 in.

SPACING OF TRANSVERSE WIRES

Transverse wires are spaced at centres of 2 in. and upwards in multiples of 1 in. Our standard spacings are 6 in., 9 in., and 12 in.

WIDTHS

The standard width of fabric for Ref. Nos. 1 to 14 is 84 inches, consisting of 28 longitudinal wires spaced at 3 in., with transverse wires projecting $1\frac{1}{2}$ in. beyond each outside wire. Ref. Nos. 611, 622, 633, 644, 655, 666, 688, and 610 are 90 in. wide, consisting of 15 longitudinal wires at 6 in. centres, with transverse wires projecting 3 in. beyond each outside wire.

LENGTHS

A.R.C. Fabric is supplied in rolls or flat sheets. Ref. Nos. 1 to 5 are stocked in sheets 17 ft. 3 in. long.

Ref. Nos. 6 to 8 are stocked in rolls 180 ft. long, and also in sheets 20 feet long.

Ref. Nos. 9 to 14 are stocked in rolls 240 ft. long and No. 9 also in sheets 15 ft. long.

Ref. No. 611 is stocked in sheets 17 ft. long.

Ref. Nos. 622, 633, 644, 655 and 666 are stocked in rolls 180 ft. long, and also are usually obtainable in sheets 20 ft. long.

Ref. Nos. 688 and 610 are stocked in rolls 240 ft. long.

Revised 1959, see tables.

STANDARD SIZES

The following tables on pages 29 and 30 give particulars of sizes, weights, strength, and shipping dimensions of our standard reinforcement fabrics which can normally be supplied at short notice. Special lengths or widths can be made to order, **but standard sizes are more readily obtainable.**

A.R.C. FABRIC

SPECIFICATIONS OF STANDARD MESHES

A.S.A84 Ref. No.	A.R.C. Ref. No.	Distance centre to centre of wires		Gauge of wires		Sectional area per foot width (sq. in.)	Nominal weight per sq. yd. (lb.)
		Main (in.)	Cross (in.)	Main S.W.G.	Cross S.W.G.		
301	1	3	8	4/0	2	.5027	18.11
302	2	3	8	3/0	2	.4348	16.04
303	3	3	8	2/0	3	.3805	13.92
304	4	3	8	1/0	3	.3298	12.37
305	5	3	8	1	3	.2828	10.93
306	6	3	12	2	2	.2393	9.14
307	7	3	12	3	3	.1996	7.63
308	8	3	12	4	4	.1691	6.46
309	9	3	12	5	5	.1412	5.40
310	10	3	12	6	6	.1158	4.42
312	12	3	12	8	8	.0804	3.07
314	14	3	12	10	10	.0515	1.97
601	611	6	6	1	1	.1414*	8.65
602	622	6	6	2	2	.1197*	7.32
603	633	6	6	3	3	.0998*	6.10
604	644	6	6	4	4	.0845*	5.17
605	655	6	6	5	5	.0706*	4.32
606	666	6	6	6	6	.0579*	3.53
608	688	6	6	8	8	.0402*	2.46
610	610	6	6	10	10	.0257*	1.57
—	333	3	3	3	3	.1996*	12.20
—	335	3	3	5	5	.1412*	8.64

* In each direction.

(Revised 1959)

A.R.C. FABRIC

PROPERTIES OF STANDARD SIZES

A.R.C. Ref. No.	Width of Standard Roll or Sheet	Length of Standard Roll (Ft.)	Length of Standard Sheet (Ft.)	Contents of Standard Roll (Sq. Yds)	Contents of Standard Sheet (Sq. Yds)	Weight of Standard Roll (lbs.)	Weight of Standard Sheet (lbs.)
1	7′-0″	Sheets only	18		14		254
2	7′-0″		18		14		225
3	7′-0″		18		14		195
4	7′-0″		18		14		173
5	7′-0″		18		14		153
6	7′-0″	180	18	140	14	1280	128
7	7′-0″	180	18	140	14	1068	107
8	7′-0″	180	18	140	14	904	90
9	7′-0″	240	18	186⅔	14	1008	76
10	7′-0″	240	18	186⅔	14	825	62
12	7′-0″	240	Rolls only	186⅔	—	573	—
14	7′-0″	240		186⅔	—	368	—
611	7′-6″	Sheets only	20	—	16⅔	—	144
622	7′-6″	180	20	150	16⅔	1098	122
633	7′-6″	180	20	150	16⅔	915	102
644	7′-6″	180	20	150	16⅔	776	86
655	7′-6″	180	20	150	16⅔	648	72
666	7′-6″	180	20	150	16⅔	530	59
688	7′-6″	240	20	200	16⅔	492	41
610	7′-6″	240	Rolls only	200	—	314	—
333	7′-0″	Sheets only	10		7.78	—	95
335	7′-0″		10		7.78	—	67

(Revised 1959)

A.R.C. INDUSTRIAL MESHES

We also manufacture other meshes for non-reinforcing purposes, such as industrial crates, machine guards, wash troughs, fencing, safety mesh for roofs, etc., from either bright or galvanised wire.

For these purposes, we can supply any size longitudinal wire from 4/0 to 14 gauge inclusive, spaced at 3 in. centres and multiples thereof, or at 2 in. centres and multiples of 2 in., provided the gauge of wire is less than No. 5.

Transverse wires can be supplied in any gauge from 1 to 14 inclusive, spaced at 2 in. centres and multiples of 2 in., or at 1 in. centres and multiples of 1 in., provided the gauge of wire is less than No. 7.

CEMENT

The main types of cement used in concrete work in this country are:—

1. Portland cement (ordinary).
2. High alumina cement.
3. Portland cement (rapid hardening or high early strength).
4. Low heat cement.

PORTLAND CEMENT

Portland Cement is used for most reinforced concrete work in this country. The standard product is fully described and specified in the Australian Standard No. A2, Portland Cement and High Early Strength Portland Cement. It is a product which, if obtained from a reliable maker, can be depended upon, and the manufacturer's brand should be upon each bag.

HIGH ALUMINA CEMENT

High Alumina Cement has been introduced comparatively recently and differs radically from Portland Cements both in properties and composition. It has an initial setting time of approximately three hours, similar to slow setting ordinary Portland cement, but has the useful quality of hardening so rapidly that after 24 hours it has a compressive strength for 1 : 2 : 4 concrete approximating 5,000 lbs. per square inch, which is as high as can be obtained with other cements only after periods of 7 to 28 days.

This rapid hardening quality permits of the earlier removal of formwork, and where repeat formwork is used, reduces the cost of the work. It is also claimed to be resistant to fire, sea-water, and certain chemicals.

It should not be mixed with Portland cements, and on account of the rapid hardening and the heat generated in setting, special attention must be given to curing the concrete.

HIGH EARLY STRENGTH CEMENT

(Rapid Hardening Cement)

High early strength cement is very similar in chemical composition to ordinary Portland cement, but finer grinding produces rapid hardening qualities. This also increases the strength of the concrete compared with that of concrete made with ordinary Portland cement.

It is useful for construction where speed in removing the formwork is required.

LOW HEAT CEMENT

Low heat cement manufactured in Australia serves the dual purpose of controlling shrinkage in mass concrete work by virtue of its low heat of hydration and consequent lower temperature of setting, and of high resistance to chemical action of sulphates.

FINE AGGREGATE

The best fine aggregate for use in reinforced concrete work is a clean, well-graded natural sand, which should be composed of hard siliceous grains and should be chemically inert and free from excessive quantities of dust, soft or flaky particles, shale, clay, or organic substances. The grains can be round or angular, provided that the material is clean and well graded.

Fresh water river sands are often naturally clean, although sometimes they may be contaminated with mud. Pit sands occasionally contain organic matter and may require washing. The screenings from crushed stone are sometimes used, but they must be free from an excessive amount of dust, and the particles should not be too flaky or splintery.

In a good sand, all the particles should pass through a British Standard sieve having a 3/16 in. mesh, and should be retained on a No. 100 B.S. sieve. Between these limits, it should have suitable proportions of all intermediate sizes. When an available sand is not suitably graded, a satisfactory material can be obtained by mixing two or more sands. The S.A.A. Draft Doc. 233, 1952, fixes limits for the properties of a representative sample for Class A sand which may pass through the meshes of a set of B.S. sieves as below.

B.S. Sieve	Natural sand or crushed gravel sand.	Crushed stone sand.
	Percentage Passing	
3/16 in.	95 - 100	90 - 100
No. 7	70 - 100	60 - 100
No. 14	45 - 85	40 - 80
No. 25	25 - 60	20 - 50
No. 52	5 - 30	5 - 30
No. 100	0 - 10	0 - 15

Sea sand may be suitable if taken from below high water level; if taken from above this level, it may have an excessive amount of salt. Generally, sea sands are deficient in grading, being too fine and uniform in nature, and often contain organic impurities due to marine life. The salt content may cause efflorescence on the surface of the finished concrete.

TESTING

The tests for grading, proportion of silt, and presence of organic matter, are given in S.A.A. Code CA2, but as these tests are suitable for the laboratory, the following simple field tests may be conveniently made on the job.

The grading test requires a set of B.S. sieves. The presence of silt, loam, or clay can be determined using an ordinary graduated medicine bottle, or preferably a measuring cylinder. Sand is placed in the bottle until it is about a quarter filled and a salt solution (1 teaspoonful to 1 pint of water) is then added until it is threequarters full. The bottle is shaken vigorously and the solution allowed to settle for 3 hours, by which time the silt will have settled down on the surface of the sample. The sample of sand is suitable provided that the percentage by volume of silt does not exceed 6 per cent., i.e., if the depth of sand in the bottle is 2 in., the depth of silt overlying it should not exceed $\frac{1}{8}$ in.

The test for organic matter may be made by using a 3 per cent. solution of sodium hydroxide (caustic soda). A bottle or measuring cylinder should be one-quarter filled with sand and the sodium hydroxide solution is added until the level reaches the half-way mark. The bottle is then stoppered, shaken vigorously, and left to stand 24 hours. If organic matter is present the solution will assume a colour varying from light straw to brown, depending on the degree of contamination. It can be assumed, that if no change in colour takes place, or if it turns no darker than light straw, the sand is safe to use. A standard colour solution can be prepared by adding $2\frac{1}{2}$ c.c. of a 2 per cent. solution of tannic acid in 10 per cent. of alcohol to $97\frac{1}{2}$ c.c. of 3 per cent. sodium hydroxide solution. The mixture should be vigorously shaken and allowed to stand for 23 hours. It should then be shaken and allowed to stand for a further 1 hour before comparison with the liquid above the sand under test. Any sand tested giving a liquid not darker than the standard solution may be taken as satisfactory as regards organic impurities.

BULKING OF SAND

Sand as received on the job is usually damp, and it is difficult to measure out accurately owing to the fact that damp sand may occupy about 40 per cent. more space than dry sand. The proportions of sand specified in the mixture assume that the sand is dry, and it is necessary to make occasional tests on the job to ascertain what volume of damp sand should be added to give the correct amount. This can easily be done by half filling a measuring cylinder with sand, which must be dropped in loosely, adding water to the threequarters mark and shaking vigorously. After it has settled, the sand will occupy exactly the same volume as it would have done if dry. From this it is possible to determine how much of the damp material should be used to give the correct amount of sand in the mix.

COARSE AGGREGATE

The essential properties of coarse aggregate are hardness, cleanliness, chemical inertness, suitability of shape, and for certain construction, resistance to fire. The material should not contain soft, friable, elongated, or laminated particles, nor be contaminated by adherent coatings or admixtures of loam, clay or organic matter. The selection is largely determined by what is available locally at a reasonable price, the most common aggregates being gravel and crushed stone, although for certain conditions, artificial aggregates such as broken brick and blast furnace slag may be suitable. Generally, gravel or crushed stone should be used for reinforced concrete work. A large number of natural rocks can be crushed and form excellent aggregates.

Basalt and quartzite are hard, chemically stable, and usually crush into angular pieces with few flaky pieces. The surfaces are rough, so that the cement and sand in the concrete mixture adhere firmly.

Granite is an excellent aggregate, provided that it is sound and not partially decomposed. Those containing flakes of mica or partially decomposed felspar should be avoided.

Flint is hard, but is apt to splinter during crushing, producing a large proportion of sharp, pointed fragments. Such an aggregate makes a harsh concrete, which spalls badly when exposed to fire.

Limestone varies from hard crystalline rock to a soft chalky material. Hard crystalline limestone is suitable, but it must be reasonably free from limestone dust. Due to the danger of

chemical action between the sulphur fumes and the carbonate in the aggregate, it should not be used for chimney construction.

Broken brick is not usually satisfactory for reinforced concrete work unless the bricks are of good quality, hard, and free from lime mortar, plaster, or brick dust. Owing to its porosity, it should not be used for impermeable construction.

Provided carefully selected material is used, a suitable aggregate can sometimes be obtained by crushing blast furnace slag. It is important that the slag should have a low sulphur content, but few comply with this requirement. Unless a satisfactory analysis of the slag is available, it is best left alone if suitable crushed stone or gravel is available.

Many sandstones are totally unsuited for concrete work, and even where a hard sandstone is used, the resulting concrete is often porous and not suitable for impermeable construction.

Gravel may be obtained from either pits or river beds, and is usually found in association with sand. Gravel consists of the water-worn fragments of any of the rocks previously mentioned. As the stones are rounded, gravel aggregate produces a more workable mix with the same quantity of water as compared with crushed stone aggregate, but is not generally suitable for roads or surfaces subject to abrasion. It may require washing to remove loam and clay.

GRADING

Coarse aggregate, whether crushed stone or gravel, should be well graded from the smallest particle of $\frac{1}{4}$ in. nominal size up to the largest size specified for the work — usually $\frac{3}{4}$ in. The maximum size should not exceed one-quarter of the minimum thickness of the concrete.

The S.A.A. Draft Doc. 233, 1952, limits the proportions of the various sizes which may be present in a nominal size aggregate as shown below.

$\frac{3}{4}$ in. NOMINAL MAXIMUM SIZE

Passing $1\frac{1}{2}$ in. B.S. sieve	100 per cent.
Retained on a $\frac{3}{4}$ in. B.S. sieve	Not more than 5 per cent.
Passing $\frac{3}{4}$ in. and retained on a $\frac{3}{8}$ in. B.S. sieve	Not more than 55 per cent.
Passing $\frac{3}{8}$ in. and retained on a 3/16 in. B.S. sieve	Not less than 25 per cent.
Passing a 3/16 in. B.S. sieve	Not more than 10 per cent.

TESTS

On the site, the only necessary test is to check the grading, as the type, suitability, and cleanliness can usually be determined from inspection.

COMBINED AGGREGATE

Sometimes a combined or "all-in" aggregate, ranging from $\frac{3}{4}$ in. material down to sand, is used. It is seldom, however, that aggregate is found naturally proportioned with the correct amounts of coarse and fine aggregate, and the proportions vary throughout the deposit. It is preferable that the coarse and fine aggregate should be delivered to the job separately, where they can be mixed in the specified proportions. Generally, combined aggregate should not be regarded as satisfactory for major reinforced concrete work unless the coarse and fine components are combined in the proportions stipulated in S.A.A. Code CA2.

When an "all-in" aggregate is used, the proportion of aggregate to cement should be only slighter greater than the amount of coarse aggregate when separate materials are used. For example, the equivalent of 1 : 2 : 4 mix would be approximately one part cement to about four and a quarter parts of "all-in" aggregate. Sometimes a mistake is made and six parts of combined aggregate are used with one part of cement, which neglects the fact that with separate materials, the two parts of sand fill the voids in the coarse material and do not increase its volume to any appreciable extent.

GAP-GRADED AGGREGATE

Due to the difficulty sometimes experienced in obtaining continuous graded aggregates, attention has recently been directed to gap-gradings which omit some of the intermediate sizes.

It is quite possible to produce good concrete using such aggregates, but due to the high sensitivity of these mixes to changes in water content and the increased danger of segregation in wet mixes, they should preferably be used only for low-slump high strength concrete under strict job control conditions.

WATER

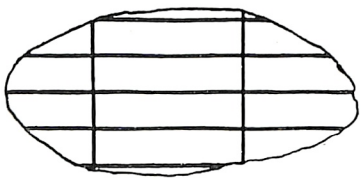
Only clean fresh water should be used for mixing concrete. Generally, any water which can be safely used for drinking purposes will be satisfactory.

DRAWINGS, BY-LAWS AND CODES

DRAWINGS

Our chief aims in the preparation of drawings for reinforced concrete work are accuracy, simplicity, and clearness. To this end we use, where possible, a standard method of detailing, which has been found extremely satisfactory.

It is our practice to make each drawing as complete as possible, to reduce the need for cross-reference between a number of drawings. The direction in which the main or longitudinal wires of the fabric are to lie is normally indicated on the plan thus:—



Notes are also included on the drawing giving the mixture of concrete, the concrete cover, and any other special points requiring attention. If required, a specification for the reinforced concrete construction is also supplied.

BY-LAWS AND CODES

Generally, our standards of reinforced concrete design are governed by the S.A.A. Code No. CA2 for concrete in building, and in certain capital cities, by local by-laws such as the Uniform Building Regulations of Victoria, and Sydney City Council Code, which differ slightly in minor details.

As the revisions necessary to modernise the S.A.A. Code are not yet completed, common practice is to allow a compressive working stress of 750 lbs. per sq. in. for normal 1 : 2 : 4 concrete, and a tensile stress of 18,000 lbs. per sq. in. for M.S. Bars. In the revised Code, these figures will probably be increased to 900 and 20,000 lbs. per sq. in. respectively, with a tensile stress of 27,000 lbs. per sq. in. for A.R.C. Fabric, which is well below half the yield point of this high tensile steel.

The Code specifies minimum requirements for concrete buildings and structures of normal type. It is not completely applicable to the design of structures such as bridges, tanks, reservoirs, etc. Tanks and reservoirs are dealt with in the Code of Practice for the Design and Construction of Reinforced Concrete Structures for the Storage of Liquids, issued by the Institution of Civil Engineers.

The minimum superimposed live loads for buildings are given in the S.A.A. Interim Code No. 350 for Loads on Buildings, the main features being shown on page 63.

Modern practice tends towards the use of lower superimposed loads and higher compressive stresses in the concrete, and this calls for care and intelligence in their use, together with a high standard of workmanship on the site.

CONTINUITY IN REINFORCED CONCRETE STRUCTURES

Structures of composite or mixed construction have little rigidity at the joints of the members. A reinforced concrete frame structure, however, is monolithic, each member being restrained at its ends by other members, and the loading of one beam affects the adjacent beams and the columns supporting them. As a result, the deflection and stress in the loaded beam is reduced, resulting in lighter and more economical members.

Typical examples of continuity are the interaction under bending of:—

(a) Continuous beams.
(b) Beams and external columns above and below in factory and similar structures.
(c) Adjacent beams and columns above and below in the interior of these structures.
(d) The floor and side walls of a tank or reservoir.

In many cases allowances for continuity and secondary stresses cannot be ascertained by exact calculation, and it is in such circumstances that the experience and training of the designer are necessary. It is most important that he should be able to recognize where secondary stresses, which are not always subject to calculation, are likely to occur, and what provision for them is required.

The designer must also be in close touch with practical matters, so that his designs, whilst incorporating the result of the latest technical research, are simple and clear cut, avoiding, as far as possible, complications in detail and arrangement of reinforcement, which, in the hands of an inexperienced designer, might lead to great difficulty in placing and ramming the concrete.

APPLICATIONS

FOUNDATIONS

The foundation is one of the most important parts of a structure, and until recently it was often the part about the design of which least was known.

In the design of foundations, essential requirements are that the settlement of the structure shall be a minimum, and if settlement occurs, it should be uniform throughout the structure.

The first condition may be provided for by having the footings of such area that the safe bearing capacity of the soil is not exceeded. As normally it is the dead load that has the greatest effect in producing settlement, foundations should be proportioned for equal unit pressures under dead load, or in certain cases such as warehouses, dead load plus some proportion of live load.

Reinforced concrete is particularly suitable for foundations, due to its strength and economy.

PRELIMINARY INVESTIGATIONS

Before commencing the design of major building works, it is always desirable to make a proper study of the site conditions. Sometimes reliable data is available from the result of previous adjacent excavations, but it is often advisable to sink test holes or borings. If a good foundation is not found at a reasonable depth, it may be necessary to have borings made to explore the ground to a greater depth; one or two test pits should be taken down well below the proposed foundation level, as it may be found that a soft stratum lies underneath strata of much better quality.

As these methods may be too expensive for minor works, a rough check can be made by driving a steel rod about $\frac{3}{4}$ in. diameter some feet into the foundation strata. Under successive and equal hammer blows, the rod should not penetrate further than for the preceding blow.

Some types of foundation are dealt with below:

ROCK

When rock is found at a convenient level, it is usually only necessary to verify that bed-rock has been found, inspect for

faults and inclined strata, and making sure that it is not a thin layer overlying soft material.

GRAVEL

Gravel in compact beds forms a reliable foundation.

They vary in bearing capacity, depending upon the nature of the matrix. If the matrix is wet sand, the gravel is usually unreliable.

CLAY

Clay can be a difficult foundation material, although a dry clay may form an excellent foundation of good bearing capacity. As some clays are soft and plastic, in such cases some allowance should be made for settlement, and the foundations designed to give uniform loading under dead load. Many clays are adversely affected by changes in climatic conditions. In summer, they dry out, shrink, and fissures may form to considerable depth; they expand again after rain, soften, and possibly flow due to the amount of water absorbed.

Where this type of clay is met, properly designed foundations may be:

1. Taken down to a depth below the level of seasonal moisture change.
2. Within the region of seasonal moisture change, but sufficiently rigid to ensure that the structure rise and fall evenly throughout.
3. Within the lower part of this region, but loaded sufficiently heavily to minimise expansion of the soil when the soil becomes saturated.

Where plastic soils of this nature are encountered, expert advice should be obtained as to the best type of foundation to adopt. Any excavations in clay should not be left open longer than necessary, as the surface may become slurry in wet weather, or dry out and crack in dry weather.

SAND

Sand when dry, or even when damp, forms a good foundation provided it cannot spread laterally or be washed out. However, when it is very fine and saturated, it may become slushy and flow under even small loads unless restraint is provided.

Care must be taken to ensure that the footings are taken down to a sufficient depth to avoid being undermined by future adjacent excavations.

ALLUVIAL DEPOSITS

Mud, silt, etc., are undesirable foundation materials. If a foundation must be placed on such materials, only a light loading is permissible. A raft foundation may be considered, but for important structures, piles will usually be necessary. In such a case, borings should be taken to determine the length of piles necessary.

BEARING TESTS

The safe bearing value to be adopted in a design often requires very careful consideration.

Load tests of soils on the site are one source of helpful data.

A suggested method of making a ground bearing test is shown on page 43.

The limit of safe bearing capacity of the ground is reached when progressive settlement occurs without change of load, and an adequate safety factor should be allowed on this figure.

This limit is clearly shown if a graph is drawn connecting load with settlement. If there is no well-defined yield point of the soil, the safe bearing capacity may be determined by the method given in the text at the top of the diagram.

It should be remembered that these tests will not disclose the effect of long term loading, seasonal effects on the soil, or heavy loading over large areas.

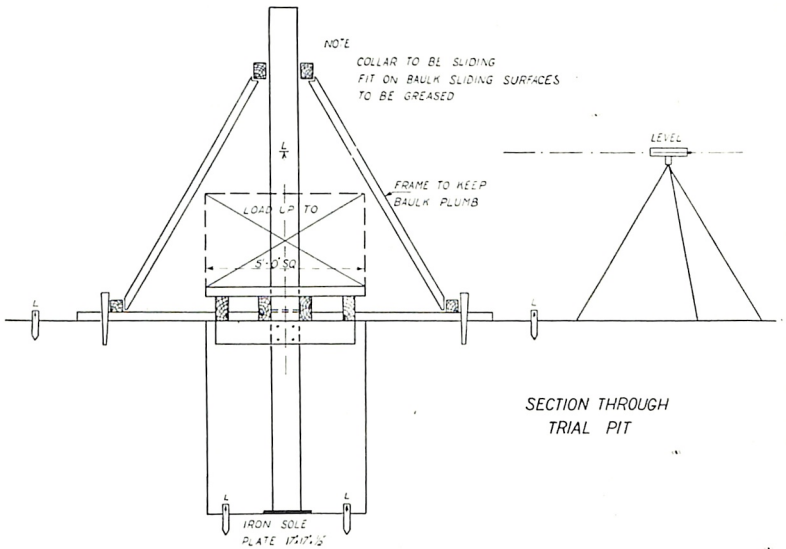
However, it can be assumed that if the soil cannot support such small load without excessive settlement, its behaviour will be worse under large loads applied permanently.

GENERALLY ACCEPTED SAFE PRESSURES ON FOUNDATIONS

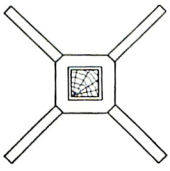
Type of Material	Tons per square foot
Alluvial soils, made ground, very wet sand	Up to ½
Soft clay or loam	½ to 1
Ordinary clay and dry sand mixed with clay	2
Dry sand and dry clay	3
Hard clay and firm coarse sand	4
Shale rock	Up to 8
Sandstone	12 to 30
Basalt	Up to 40

DETAILS OF CONSTRUCTION FOR GROUND BEARING TEST

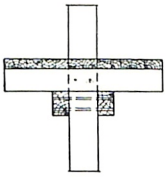
APPLY TEST LOAD EQUAL IN INTENSITY TO THE PROPOSED DESIGN LOAD. LEAVE UNDISTURBED FOR 24 HOURS AFTER SETTLEMENT HAS CEASED. THEN DOUBLE THE LOAD BY APPLYING AT LEAST 4 EQUAL INCREMENTS AT INTERVALS NOT LESS THAN 4 HOURS. LEAVE UNDISTURBED UNTIL 24 HOURS AFTER SETTLEMENT HAS CEASED. THE GROUND IS SATISFACTORY FOR THE PROPOSED INTENSITY OF LOADING IF THE SETTLEMENT UNDER THIS INTENSITY IS LESS THAN $\frac{1}{4}$" AND IF TOTAL SETTLEMENT THROUGHOUT TEST IS LESS THAN $\frac{1}{2}$". A FULL LOG OF READINGS AT ALL POINTS 'L' SHOULD BE KEPT THROUGHOUT TEST.


NOTE
COLLAR TO BE SLIDING FIT ON BAULK SLIDING SURFACES TO BE GREASED
LEVEL
FRAME TO KEEP BAULK PLUMB
LOAD UP TO
5'-0" SQ.
IRON SOLE PLATE 1'3"x1'3"

SECTION THROUGH TRIAL PIT



DETAIL OF COLLAR



SIDE VIEW OF PLATFORM

Fig. 6.

The terms "soft" and "hard" applied to clays are rather difficult to interpret.

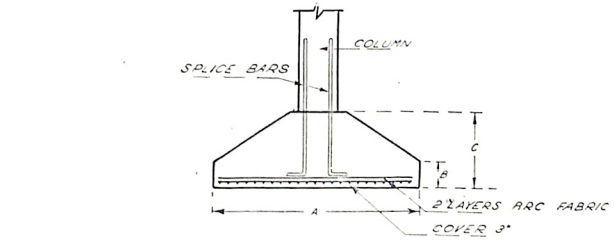
As a rough guide only when taken on fresh samples, a soft clay is one which can be moulded under relatively slight pressure of the fingers, and a hard clay one requiring picking for removal and which cannot be moulded by substantial pressure of the fingers.

More detailed figures in common use for types of plastic soils at various capital cities are given below.

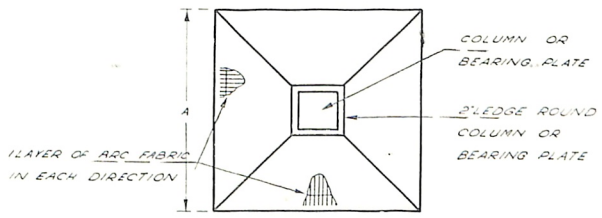
City	Soil or Locality	Tons per sq. ft.
Adelaide .	River silt	Low and variable
	Bay of Biscay soil	.4 to .8
	True marl	2
	Grey or blue clay occurring several feet below surface of city	3
Brisbane .	River silt	Low
	Stiff buff clay near Brisbane River	2
	Blue clay in suburbs	4
Canberra .	Black loam or clay top soil	1
	Decomposed shale	2
Melbourne	Silt, south and west Melbourne	.35
	Clay, western and northern suburbs	.5 to 2
	Clay, city and eastern suburbs	2.5 to 4
Perth . . .	Clay band below city area	3 to 4
Sydney . .	Clay, southern and western suburbs	1 to 2
	Clay, northern and north-western suburbs	2 to 3
Hobart . .	Irregular and local conditions	Variable but low to moderate.

TYPES OF FOUNDATIONS

(a) ISOLATED FOOTINGS: When the ground is of reasonably good bearing capacity, columns and stanchions may be most economically founded on isolated footings. These are usually square for economy, or rectangular, or irregularly shaped to conform with site restrictions, the area and thickness being determined from the bearing capacity of the ground and the load on the column. A typical detail of an isolated column foundation is shown in Fig. 6, and dimensions and reinforcement for such footings on ground of various bearing capacities are given in the tables on pages 46 and 47.



ELEVATION



PLAN OF FOOTING

Fig. 7.

COLUMN FOUNDATIONS

Reinforced with A.R.C. Fabric

* See Fig. 7.

Allowable pressure on ground.	Load on column (tons)	Assumed Min. size of square column	DIMENSIONS			Ref. No. of Fabric in base both ways
			A*	B*	C*	
	15	9"	5' 6"	9"	1' 1"	9
½ ton	20	9"	6' 6"	9"	1' 4"	8
per sq.	30	11"	7' 9"	9"	1' 8"	7
ft.	40	12"	9' 0"	9"	1' 11"	7
	50	14"	10' 0"	12"	2' 1"	6
	15	9"	4' 6"	9"	1' 1"	9
	20	9"	5' 3"	9"	1' 3"	9
¾ ton	30	11"	6' 6"	9"	1' 7"	8
per sq.	40	12"	7' 6"	9"	1' 10"	7
ft.	50	14"	8' 3"	9"	2' 0"	6
	60	15"	9' 0"	12"	2' 3"	6
	80	18"	10' 3"	12"	2' 6"	5
	15	9"	4' 0"	9"	1' 1"	9
	20	9"	4' 6"	9"	1' 1"	8
	30	11"	5' 6"	9"	1' 4"	7
1 ton	40	12"	6' 6"	9"	1' 6"	6
per sq.	50	14"	7' 0"	9"	1' 9"	5
ft.	60	15"	7' 9"	9"	1' 10"	5
	80	18"	9' 0"	12"	2' 1"	4
	100	20"	10' 0"	12"	2' 4"	4
	20	9"	3' 9"	9"	1' 0"	8
	30	11"	4' 6"	9"	1' 2"	7
1½ tons	40	12"	5' 3"	9"	1' 5"	6
per sq.	50	14"	5' 9"	9"	1' 6"	5
ft.	60	15"	6' 3"	9"	1' 8"	5
	80	18"	7' 3"	9"	1' 10"	4
	100	20"	8' 3"	12"	2' 3"	4

If the size of column adopted is less than that given in the tables, the depth of footing may need to be increased. The tables are suitable for stanchion footings provided the size of square base plate is not less than the column size shown in the tables.

COLUMN FOUNDATIONS

Reinforced with A.R.C. Fabric

* See Fig. 7.

Allowable pressure on ground	Load on column (tons)	Assumed Min. Size of square column	DIMENSIONS			Ref. No. of Fabric in base both ways
			A*	B*	C*	
	20	9"	3' 3"	9"	1' 0"	8
	40	12"	4' 6"	9"	1' 3"	6
2 tons	60	15"	5' 6"	9"	1' 6"	5
per sq.	80	18"	6' 6"	9"	1' 9"	4
ft.	100	20"	7' 0"	12"	2' 0"	4
	130	22"	8' 0"	12"	2' 3"	3
	160	25"	9' 0"	12"	2' 6"	2
	40	12"	4' 0"	9"	1' 3"	6
	60	15"	5' 0"	9"	1' 6"	5
2½ tons	80	18"	5' 9"	9"	1' 7"	4
per sq.	100	20"	6' 3"	9"	1' 9"	3
ft.	130	22"	7' 3"	12"	2' 1"	2
	160	25"	8' 0"	12"	2' 3"	2
	200	28"	9' 0"	12"	2' 6"	1
	40	12"	3' 9"	9"	1' 2"	5
	60	15"	4' 6"	9"	1' 4"	4
3 tons	80	18"	5' 3"	9"	1' 6"	3
per sq.	100	20"	5' 9"	12"	1' 9"	3
ft.	130	22"	6' 9"	12"	2' 0"	2
	160	25"	7' 3"	15"	2' 3"	1
	200	28"	8' 3"	15"	2' 6"	1
	100	20"	5' 0"	12"	1' 8"	2
4 tons	130	22"	5' 9"	15"	1' 10"	1
per sq.	160	25"	6' 3"	15"	2' 0"	1
ft.	200	28"	7' 0"	15"	2' 3"	1

(b) COMBINED AND CANTILEVER FOOTINGS: Where conditions limit the size or shape of column footings, it may be necessary to combine the footings of two or more adjacent columns to form one combined footing.

An example is a column placed on a boundary line, it thereby being impossible to provide a symmetrical footing under the column. If there is an adjacent inner column, the two columns may be placed on a combined footing.

It is necessary to ensure that the centre of gravity of the combined column loads coincides with the centre of gravity of the upward soil reaction.

In cases such as above, it is often preferable to use a cantilever footing.

An eccentric footing is provided under the external boundary column, and equilibrium is restored by introducing a tie beam or strap joining this footing to the nearest internal footing.

(c) CONTINUOUS BEAM FOUNDATIONS: Sometimes it is necessary to form a continuous foundation under a row of columns. This is done when the ground is not of good bearing capacity, and it is necessary to avoid any large relative settlement of the columns. It may also be used under a row of columns on a boundary line, where projection of the footings past the boundary is impossible, and it is impracticable to use individual eccentric footings connected to internal footings with tie beams. They may be either rectangular in cross-section or inverted "T" shape, depending on the conditions outlined above. Unless the columns are spaced regularly and are fairly close together, these footings are not economical.

(d) STRIP FOOTINGS: In general, the width is determined by the loading on the footing and the bearing capacity of the ground. Unless the footing is on rock or hard ground, we recommend they be reinforced with A.R.C. Fabric longitudinally and/or transversely, depending on the circumstances.

(e) INVERTED "T" BEAM FOUNDATIONS: In poor soils, continuous footings of this type are often used instead of normal strip footings, either at or below the surface.

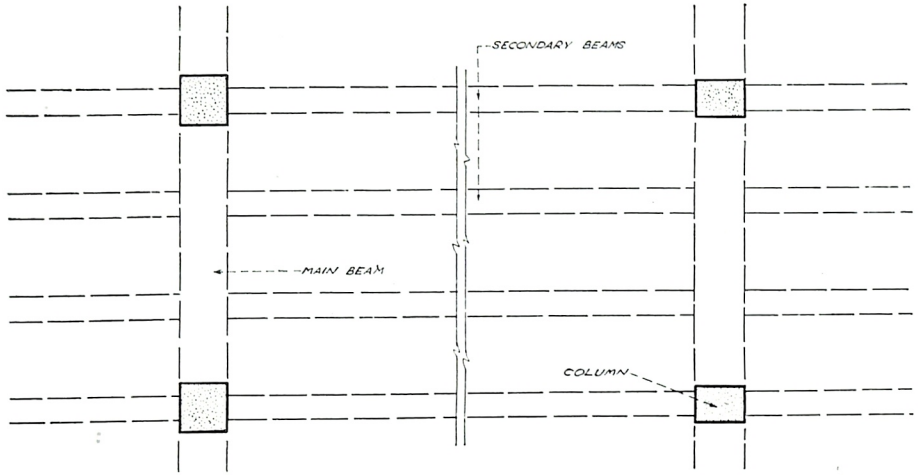
For such a case, the depth of stem should be proportioned to give a footing of sufficient rigidity to limit the cracking

of the superstructure. We recommend that expert advice be obtained for this type of footing, as no general rules for design can be offered.

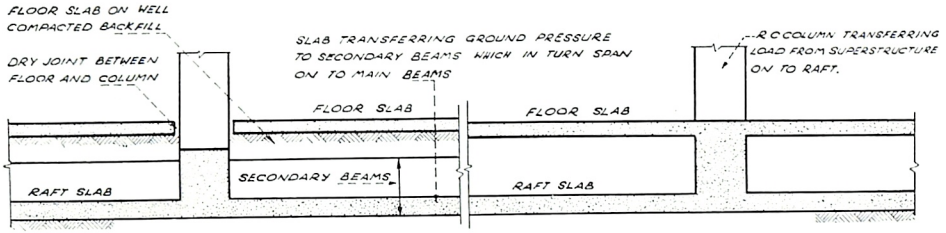
(f) BEAM AND PIER FOUNDATIONS: When ground of good bearing capacity can be found only at some considerable depth, say between five and fifteen feet depth below the surface, it is often economical to excavate holes for individual footings. Piers are erected on these bases, supporting beams which carry the superstructure. Where the beams support walls, the position and spacing of the piers is determined by the layout, and the depth to the firm strata.

(g) PILES: When the weight of the structure exceeds the bearing capacity of the soil, it may be necessary to support it on piles driven to a hard stratum. Except where a single pile is sufficient, a reinforced concrete cap is used to spread the concentrated load from a column or stanchion over a group of piles. Under a brick bearing wall, a continuous staggered line of piles with a continuous cap may be used. Alternatively, the wall may be supported on a continuous footing beam spanning between groups of piles having reinforced concrete caps. Where a hard stratum cannot be found at a reasonable depth, the piles must be long enough to carry their loads by skin friction. Details of A.R.C. piles are shown on page 55.

(h) RAFTS: Where the bearing capacity of the ground is very low, it is sometimes necessary to distribute the weight of the structure over the whole area of the building, so that the foundation becomes a reinforced concrete "raft". This type of foundation is always uneconomical. Typical arrangement of two types are shown on page 50, one in which the floor slab forms part of the raft, and in the other the floor is constructed independently.



PLAN OF RAFT


FLOOR SLAB ON WELL COMPACTED BACKFILL
DRY JOINT BETWEEN FLOOR AND COLUMN
SLAB TRANSFERRING GROUND PRESSURE TO SECONDARY BEAMS WHICH IN TURN SPAN ON TO MAIN BEAMS
R C COLUMN TRANSFERRING LOAD FROM SUPERSTRUCTURE ON TO RAFT.
FLOOR SLAB
FLOOR SLAB
RAFT SLAB
SECONDARY BEAMS
RAFT SLAB

RAFT WITH FLOOR SLAB RESTING ON FILLING.

RAFT WITH FLOOR SLAB SUPPORTED ON SECONDARY BEAMS, CELLULAR CONSTRUCTION.

FOOTINGS FOR HOUSES OF BRICK OR SIMILAR CONSTRUCTION

Generally, for soils of reasonable behaviour and moderate bearing capacity, we suggest the following **minimum** sizes of footings.

Single storey, external 11 in. — 1 ft. 6 in. wide by 10 in. thick at a minimum depth of 1 ft. 6 in.

Single storey, internal 4½ in. — 1 ft. 3 in. wide by 10 in. thick at a minimum depth of 1 ft. 6 in.

Two-storey, external 11 in. — 2 ft. wide by 10 in. thick at a minimum depth of 1 ft. 6 in.

Two-storey, internal 4½ in. — 1 ft. 6 in. wide by 10 in. thick at a minimum depth of 1 ft. 6 in.

Due to the variable loading on the footing caused by window openings, etc., and the possibility of soft patches in the soil, we recommend for each case reinforcing with not less than No. 9 A.R.C. Fabric top and bottom.

The following tables give the equivalent fabric for specified numbers of M.S. bars in strip footings of various widths from 1 ft. to 3 ft., such as for house foundations. Table 1 is for ⅜ in. diameter bars, and Table 2 for ½ in. diameter bars.

When the fabric shown in the appropriate column under the heading "Width of Footing" is used, the concrete cover at the sides of the fabric longitudinal wires will be 3 in. The decimal figures below the fabric reference number give the actual area provided by using the given fabric, e.g. if five ⅜ in. diameter rods are specified in a footing of width 2 ft., No. 6 A.R.C. is the equivalent, using seven longitudinal wires giving a cross-sectional area of .42 sq. in.

Selecting a fabric in the next space to the right reduces the side cover to 1½ in., which is undesirable in footings. Moving to the left in the table, it will be noticed that instead of seven wires of No. 6 A.R.C., six wires of No. 5 or five wires of No. 4 A.R.C. provide the required area, but the side cover will be increased to 4½ in. or 6 in., respectively.

TABLE 1 FOR 3/8" DIAMETER BARS

No. Bars specified	Total Area of Bars (sq. in)	Area of Equiv. Fabric (sq. in)	WIDTH OF FOOTING and recommended No. of Wires on Fabric to give 3in. Side Cover								
			12 In.	15 in.	18 in.	21 in.	24 in.	27 in.	30 in.	33 in.	36 in.
			3 wires	4 wires	5 wires	6 wires	7 wires	8 wires	9 wires	10 wires	11 wires
1-3/8"ø	.110	.079	No. 10 .087	No. 12 .080	No. 12 .10	No. 14 .077					
2-3/8"ø	.221	.159	No. 7 .15	No. 8 .169	No. 9 .177	No. 10 .174	No. 10 .203	No. 12 .161	No. 12 .181	No. 12 .201	No. 12 .221
3-3/8"ø	.331	.238	No. 4 .247	No. 6 .239	No. 7 .25	No. 8 .254	No. 9 .247	No. 10 .232	No. 10 .261	No. 10 .29	No. 12 .221
4-3/8"ø	.442	.318	No. 2 .326	No. 4 .33	No. 5 .354	No. 7 .30	No. 7 .35	No. 8 .338	No. 9 .318	No. 9 .353	No. 10 .319
5-3/8"ø	.552	.397	No. 1 .377	No. 2 .435	No. 4 .412	No. 5 .424	No. 6 .42	No. 7 .40	No. 8 .381	No. 8 .423	No. 9 .988
6-3/8"ø	.662	.477	2/No. 4 .494	No. 1 .503	No. 3 .476	No. 4 .494	No. 5 .495	No. 6 .48	No. 6 .54	No. 7 .499	No. 8 .465
7-3/8"ø	.773	.557	2/No. 3 .571	2/No. 5 .566	No. 2 .544	No. 3 .571	No. 4 .577	No. 5 .566	No. 6 .54	No. 6 .598	No. 7 .55
8-3/8"ø	.883	.636	2/No. 2 .652	2/No. 4 .659	No. 1 .629	No. 2 .652	No. 3 .666	No. 4 .659	No. 5 .636	No. 6 .598	No. 6 .66

TABLE 2 FOR 1/2" DIAMETER BARS

No. Bars specified	Total Area of Bars (sq. in)	Area of Equiv. Fabric (sq. in)	WIDTH OF FOOTING and recommended No. of Wires on Fabric to give 3in. Side Cover								
			12 In.	15 in.	18 in.	21 in.	24 in.	27 in.	30 in.	33 in.	36 in.
			3 wires	4 wires	5 wires	6 wires	7 wires	8 wires	9 wires	10 wires	11 wires
1-1/2"ø	.196	.141	No. 7 .15	No. 9 .141	No. 10 .145	No. 10 .174	No. 12 .141	No. 12 .161	No. 12 .181	No. 12 .201	No. 14 .142
2-1/2"ø	.393	.283	No. 3 .285	No. 5 .283	No. 6 .299	No. 7 .299	No. 8 .296	No. 9 .282	No. 10 .261	No. 10 .29	No. 10 .319
3-1/2"ø	.589	.424	2/No. 5 .424	No. 2 .435	No. 4 .412	No. 5 .424	No. 6 .42	No. 7 .40	No. 8 .381	No. 8 .42	No. 9 .388
4-1/2"ø	.785	.565	2/No. 3 .571	2/No. 5 .566	No. 2 .544	No. 3 .571	No. 4 .577	No. 5 .566	No. 6 .54	No. 6 .598	No. 7 .55
5-1/2"ø	.982	.707	1/No. 1 1/No. 2 .703	1/No. 3 1/No. 4 .71	2/No. 5 .707	No. 1 .754	No. 2 .761	No. 3 .761	No. 4 .742	No. 5 .707	No. 6 .66
6-1/2"ø	1.178	.848		2/No. 2 .87	2/No. 4 .824	2/No. 5 .848	No. 1 .88	No. 2 .87	No. 3 .856	No. 4 .824	No. 4 .91
7-1/2"ø	1.374	.99		2/No. 1 1.01	2/No. 3 .951	2/No. 4 .989	2/No. 5 .99	No. 1 1.06	No. 2 .978	No. 3 .951	No. 3 1.05
8-1/2"ø	1.57	1.13			2/No. 2 1.09	2/No. 3 1.141	2/No. 4 1.154	2/No. 5 1.13	No. 1 1.13	No. 2 1.09	No. 2 1.96

PILES

Where highly compressible soils are encountered, with a hard stratum found only at considerable depth, a foundation supported on piles is often adopted, the piles being long enough either to reach the firm sub-stratum, or to develop sufficient friction to support their loads from the structure. Reinforced concrete piles have the advantage of greater strength and permanency, and their cost will be found to compare favourably with other forms of construction.

Wooden piles are more prone to damage at the head by hard driving and the points may be crushed when driven into hard material. If they are not straight, they may deflect from the intended position during driving, and hard driving may crumple them so that the yielding may be mistaken for further penetration.

The main types of pre-cast concrete piles are Bearing piles and Sheet piles. There are a number of systems of cast-in-situ concrete piles, mostly protected by patent rights, which have definite advantages for certain conditions.

There are many considerations which determine the type of pile to be used, and each type of pile has special advantages for specific conditions.

Bearing piles are usually square or octagonal in cross-section, varying in size from 9 inches to 2 ft. overall, and are used as the main supports for different types of structure.

Sheet piles are used for quay walls and river training walls. They are usually rectangular in section, varying in size from 9 in. x 4 in. to 24 in. x 15 in. In order that they may be kept in line during driving, a groove is usually formed in one narrow side with a corresponding projection on the other side. This keeps the piles regular during driving and assists in forming a definite key and seal between each pair of piles.

A bearing pile can be constructed to carry any load up to about 80 tons. As a rule, it is not the strength of the pile proper which is the governing factor, but the capacity of the ground into which the pile is driven to support it under its maximum loading.

The cross-section of a pile is generally determined by the load which it is to carry and its unsupported length in the finished structure, a certain section being necessary to make it secure against buckling. The amount of reinforcement is usually fixed by stresses during handling and actual driving.

The calculated amount should be used merely as a guide, the actual amount being fixed as a result of previous experience of piles in similar situations.

In many types of ground, it is necessary that the lower end of the pile should be protected by a metal shoe against abrasion, the type and weight depending on the nature of the ground. It is advisable to allow for a toggle hole about 2 ft. 6 in. from the top end to facilitate fixing the pile in the driving frame. When driving reinforced concrete piles, it is desirable to use a heavier hammer than would be used for timber piles, say $1\frac{1}{2}$ to 4 tons weight, and the drop should not exceed 4 ft. It is advisable to protect the pile-head during driving with some form of steel helmet. The hammer blow is taken on a timber stub-dolly fitted into the top of the helmet, a packing being placed between the latter and the pile-head. This packing may be 2 in. or 3 in. of sawdust in bags (the thickness being measured after compression by driving), or such material as coiled hemp rope, felt, or coir mats.

The following formula may be used for assessing the approximate load which a pile should safely carry, but here again, experience must guide in addition to the results of the calculations.

$$\text{Safe load on pile (tons)} = \frac{W^2H}{d(w+p)} \div \text{Factor of Safety.}$$

Where W = Weight of hammer (tons)
H = Height of drop (inches)
P = Weight of pile (tons)
D = Average penetration of last few blows (inches)

A Factor of Safety of 5 to 10 is usually adopted.

Provided the requisite soil data is available, more exact figures may be obtained with the Hiley formula, but for all important work, test piles should be driven and loaded.

A usual set for piles is 10 blows to the inch of a $1\frac{1}{2}$ to $3\frac{1}{2}$-ton hammer falling through a height of 4 ft., the weight of hammer depending on the size of pile to be driven.

After piles are driven, it is usual to strip the heads for a depth of about 2 ft., and expose the reinforcement so that it may bond into the in-situ structure which is built above it.

Details of our standard square, octagonal, and sheet piles are shown in Fig. 8.

STANDARD A.R.C. PILES

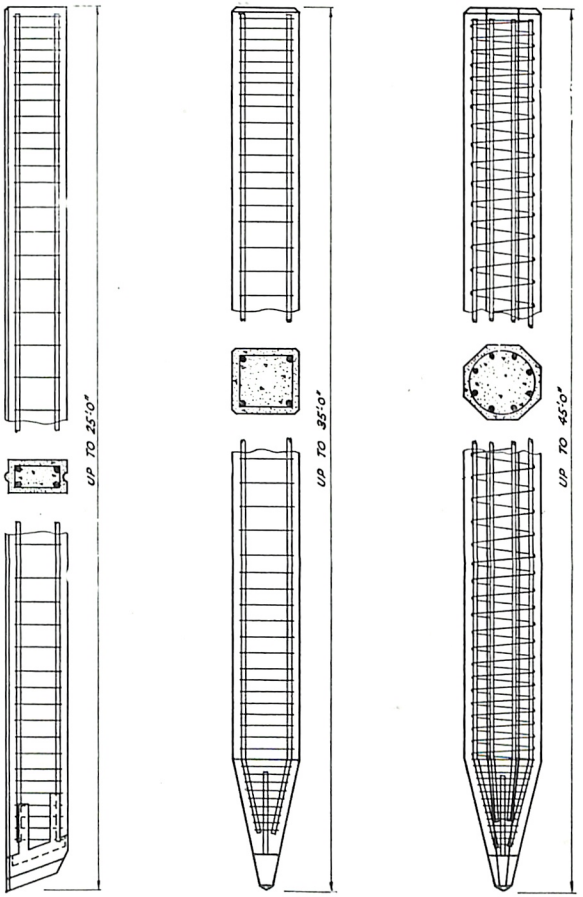


Fig. 8.

COLUMNS

A reinforced column consists of a shaft of concrete reinforced with a number of longitudinal bars encircled at intervals by wire hoops or helicals. Common shapes are square, rectangular, circular and octagonal, but an advantage of reinforced concrete is that they can be made of any shape. The amount of longitudinal reinforcement may be varied from about 1 per cent. to a practical maximum of 6 per cent., and sufficient binding hoops or helicals are provided to prevent local buckling of the reinforcement under compressive load. Splice bars are left projecting from the foundations, and the column bars are attached to them. These splice bars should be fixed by a template so that the column bars, which are assembled after the footings have been concreted, will fit accurately around them.

It has been shown from experiments that reinforced concrete columns are more fire-resisting than any other type of column, and no special protective casing has to be provided as with steel-work. The cover of concrete over the bars can be adjusted to give various standards of fire-resistance, the usual thickness being 2 inches.

In buildings such as works and warehouses, the columns do not need any finishing treatment beyond rubbing down after form-work has been removed. In offices and other buildings where some architectural effect is desired, they may be plastered or otherwise incorporated in the scheme of decoration. The safe load on a column considerably depends on the degree of fixity of the ends and its unsupported length. The strongest column is one which is rigidly framed into floor beams at its upper and lower ends, and this will carry a greater load than a similar column in which the ends are not securely held.

BEAMS

In a reinforced concrete floor the beams are not separate members like steel or timber beams, but are usually incorporated with a slab, from which the beam forms a projecting rib. Part of the economy of reinforced concrete arises from this fact, that the floor slab performs a double action. The compressive stresses in the beam are carried by the concrete slab, and steel reinforcement is provided near the bottom of the rib to take the tensile stresses. In this way both materials are distributed to carry the stresses for which they are suited.

As the concrete forming the beam is incombustible and a material of low conductivity, it affords excellent protection to the reinforcement against fire, whereas steel or timber beams require added protection.

Reinforced concrete beams may be used in most of the situations where it was formerly the custom to use brick or stone arches, or beams and lintels of timber, stone, iron or steel. There is no standardization of reinforced concrete beams and a size and shape can be arranged to suit all and every requirement. Certain proportions of beams with respect to the span and the loading are desirable on the grounds of economy, but wide variations may be made without unduly affecting the cost. Within limits the deeper a beam is made, the cheaper it becomes, but this may require to be viewed in conjunction with the cost of additional height to the building so as to provide the required headroom in each storey. Generally a layout of the supporting columns giving square, or approximately square panels, with main beams along the shorter sides of the panels, and secondary beams resting on the main beams at the third points, gives the greatest economy. The size of the bays when not fixed by architectural requirements depends on the loading on the floors and the purpose of the building.

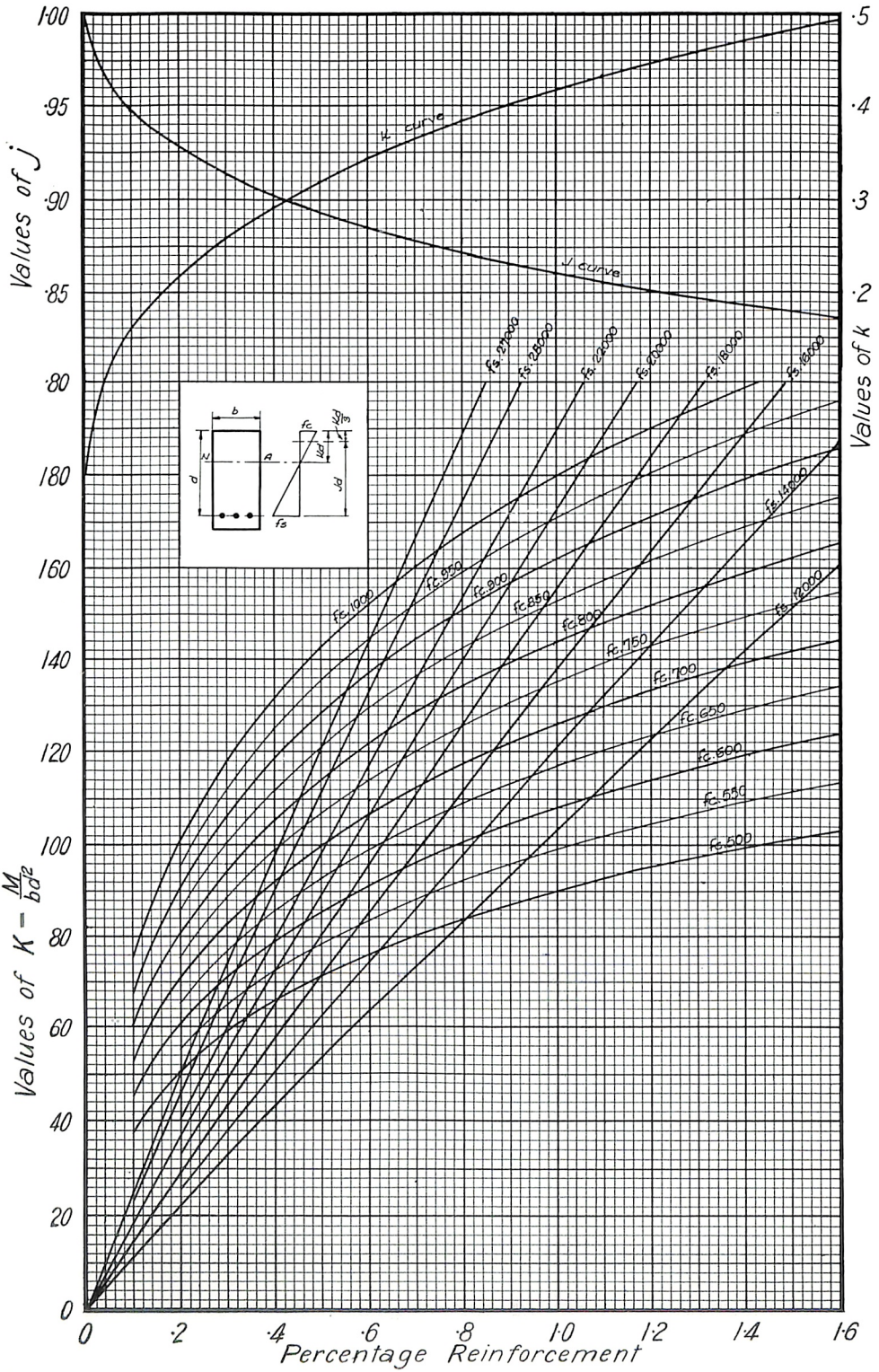
RECTANGULAR BEAMS

Rectangular beams are sometimes used as lintels or as girders on crane gantries. In such circumstances the economy of material is not so great, but particularly in the case of construction exposed to the weather, there is nothing to corrode and no painting or other maintenance work is necessary. Whilst beams are usually straight in plan so as to carry their load the shortest distance to the supports, there is no difficulty in designing and constructing reinforced concrete beams curved on plan or elevation.

REINFORCEMENT

Most reinforced concrete beams are continuous over a number of spans, giving tensile stresses at the bottom of the beams at midspan, decreasing towards the supports, and tensile stresses at the top of the beam over the supports rapidly decreasing on either side of the supports. Reinforcement in the form of mild steel bars is provided to meet these stresses.

The shearing stresses in a beam, which are usually greatest near the supports, produce diagonal tension in the web of the


Values of j
Values of k
Values of K = M/bd²
Percentage Reinforcement
j curve
k curve
fs 27000
fs 25000
fs 22000
fs 20000
fs 18000
fs 16000
fs 14000
fs 12000
fc 1200
fc 950
fc 900
fc 850
fc 800
fc 750
fc 700
fc 650
fc 600
fc 550
fc 500
b
d
n
A
fc
fs

beam, and reinforcement is required to take this tension, unless the amount is low and within the capabilities of the concrete mixture used. This may be done by bending up some of the reinforcement from the bottom of the beam at angles varying from 30 degrees to 60 degrees, and anchoring it effectively in the top portion of the beam. The remainder of the diagonal tension stress is picked up on binders or stirrups passing usually round the perimeter of the beam at right angles to the main reinforcement.

A description of A.R.C. stirrups is given on pages 20 and 21.

RECTANGULAR BEAMS AND SLABS (Chart, p. 58)

The chart is applicable to the design of both singly reinforced rectangular beams and slabs, for the latter a width of 12 in. usually being taken as the width of beam. All curves and values shown on the chart have been based on a modular ratio of steel to concrete of 15.

The bending moment in inch lbs. (M) on the section under consideration is first ascertained having regard to its system of loading and degree of restraint and continuity. To these loads must be added the self weight of the beam for which purpose a trial section is first assumed.

A value of K is now determined by dividing the bending moment by the product of the width of the section and the square of its depth in inches. $K = \frac{M}{b.d.^2}$

The maximum working stresses for concrete (fc) and steel (fs) are known for the immediate problem, being governed mainly by the quality of these two materials.

An entry is now made into the chart at the point corresponding to the value of K already computed and reading to the right until the chosen steel stress line is met, the concrete stress may readily be interpolated by reference to the curved fc lines crossing the chart at this point. Should the safe concrete working stress be not exceeded, the second reading from the chart is made by dropping down to the bottom line where the percentage reinforcement is shown. The area of steel (As) for tensile strength in the section is now found from the last reading.

$$As = \frac{\text{Percentage reinforcement x b.d.}}{100}$$

Should the safe concrete stress be exceeded, then a new trial section should be taken to satisfy all requirements.

When the safe concrete stress is exceeded for any section as revealed by the point of intersection of K and fs lines, the chart can be interpreted in yet another way by reading on to the right until the safe concrete stress line is encountered and then dropping down to obtain the percentage reinforcement. It can be seen, however, by reference to the fs lines, that the steel stress drops and the percentage reinforcement increases rapidly when this latter method is employed, and it is not to be recommended if there are no restrictions on increasing the concrete section.

By reading upwards from the percentage of reinforcement used, values of j and k as intercepted by their respective curves may be found. (Reference to the diagrammatic beam section on the chart shows how these values apply.)

Example 1.
fs = 16,000
fc = 600

Bending moment	=	360,000 inch lbs.
Section 20 in. x 10 in., b.d.^{2}	=	4,000
$K = \frac{360{,}000}{4{,}000}$	=	90
fc (interpolated)	=	580 lbs. per sq. in.
Percentage reinforcement	=	.64
$As = \frac{.64}{100} \times 20 \times 10$	=	1.28 sq. in.

Example 2.
fc = 600

Bending moment	=	480,000 inch lbs.
Section 20 in. x 10 in., b.d.^{2}	=	4,000
$K = \frac{480{,}000}{4{,}000}$	=	120
fs (inoterpolated)	=	10,000 lbs. per sq. in.
Percentage reinforcement	=	1.43
$As = \frac{1.43}{100} \times 20 \times 10$	=	2.86 sq. in.

It should be noted that the section and tension reinforcement derived from the use of the K chart must still satisfy the shear and bond requirements of the beam under consideration. It will generally be found that no further modification due to these two latter requirements is necessary for slabs and beams of long span and moderate loading.

LINTELS

Reinforced concrete lintels spanning door and window openings in brick walls are usually rectangular beams. When a number of lintels span adjacent windows they may be joined together to form a continuous beam, and also continued through the wall to produce an architectural band around the building.

The concrete mixture should be 1 part cement, 2 parts sand, 4 parts aggregate, measured by volume.

LOADING

When the ends of the lintels simply rest on piers or bearings on each side of a window they are considered as freely supported beams. In many practical cases the brickwork tends to arch itself over the opening, and only a triangular area is actually carried by the lintel. The load on the lintel may then be taken as an amount of brickwork having a height equal to one-third to one-half of the span. Where a concentrated load such as a roof truss or beam is supported on a lintel or on the brickwork just above it, the **equivalent** uniformly distributed load should be calculated and added to the other loads. When the lintel is close to the end of the wall and particularly when the pier between the side of the window and the end of the wall is narrow, it is not safe to rely upon very much arching action, and the weight of the brickwork should then be taken as a height not less than the span of the lintel.

REINFORCEMENT

The depths of lintels are determined by the load and the coursing of the brickwork, and this means that the depths vary by $3\frac{3}{8}$ in. increments from $6\frac{3}{4}$ inches upwards. The width is usually the same as the wall thickness, except where an architectural stone or brick-facing is used.

A.R.C. Fabric, used in strips of suitable width, is a very convenient form of reinforcement for concrete lintels of short to moderate spans. The fabric consists of longitudinal wires at 3 in. centres, with cross-wires at centres of 9 in. or 12 in. welded to the longitudinal wires to form a single strip of reinforcement for each lintel. The reinforcement is laid at the bottom of the lintel, with 1 in. cover of concrete, and turned up about 5 in. at each end.

PRECAST LINTELS

Lintels of small size are generally precast and built in as the brickwork is erected. It is very important that the top side should be distinctly marked to avoid any possibility of placing them the wrong way up.

SUSPENDED FLOOR SLABS

DESIGN OF FLOORS

In designing reinforced concrete floors, it is customary to assume that the floor will carry a certain uniformly distributed load, the amount depending on the purpose for which the floor is to be used. In addition to this, provision is often made for local heavier concentrations of loading which may be caused by heavy furniture, safes, or vehicle wheel loads.

LOADING

There is some variation in the loads which are taken on floors for various purposes, and the following table giving the particulars of the minimum loadings required by the Standards Association of Australia (Interim Code No. 350) shows the trend of modern practice towards lower superimposed loads.

Type of Occupancy	Minimum uniformly dist. loads (lbs. per sq. ft.)	Critical Span (ft.)		Concentrated or other Special Load
		Slabs	Beams, Joists, Ribs	
Boiler rooms, theatre stages	150	—	—	—
Public assembly, stairways, public halls, dance halls, theatres, factories, workshops, grandstands with movable seats, corridors to grandstands	100	—	—	—
Garages and vehicle workshops	100	—	—	To be determined but not less than 7,000 lbs. conc. on area 6" x 6"
Offices (public spaces only) file rooms, and retail shops	100	7	11	—
Hotel lounges and dining rooms, corridors, school assembly rooms	80	4.5	5.5	—
Churches (movable seats) school class rooms, grandstands (fixed seats)	60	5	7	—
Car Parks	60	—	—	3,000 lbs. concentrated on area 4" x 4"
Library reading rooms	50	5.5	9	—
Restaurants	50	4.5	5.5	—
Offices	50	10	23	—
Hotel bedrooms, hospital wards, churches (fixed seats), domestic buildings over 2 storeys	40	6.5	11	—
Sleeping dormitories, domestic buildings less than 2 storeys	30	7	15	—
Flat roofs for multi-storey city buildings	60	—	—	—
Flat or pitched roofs not exceeding 10°	30 or $3 \times \frac{200}{(L+4)}$ whichever is the greater	—	—	L = span in feet

Where the span of the member under consideration is less than the critical span, the uniformly distributed load given in the second column shall be increased as follows:—

(a) For slabs, the unit load on the panel shall be increased as the square of the ratio of the critical span to the span under consideration. (For two-way slabs, the small span.)

(b) For ribs or beams, etc., spaced at less than 4 ft. cts., the unit loading on the member shall be increased as the ratio of the critical span to the span of the member under consideration.

(c) For ribs, beams, etc., spaced at more than 4 ft. cts., the unit loading on the member shall be increased as the ratio of 4 times the critical span to the area supported by the member, where that ratio is not less than 1.0.

DEAD WEIGHT OF FLOOR

The dead weight of the floor, which may vary from 30 to 100 lbs. or more per square foot, must also be taken into account. The following are the weights per square foot for various thicknesses of concrete floor.

Thickness of floor in inches ..	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$
Weight of floor in lbs. per ft. super	31	37	44	50	56	62	69
Thickness of floor in inches ..	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9
Weight of floor in lbs. per ft. super	75	81	87	94	100	106	112

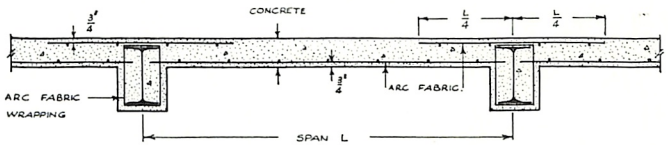
The dead weight of the floor cannot be ignored because it represents, particularly with the superimposed loads now permissible, a large proportion of the total weight to be carried.

TABLES

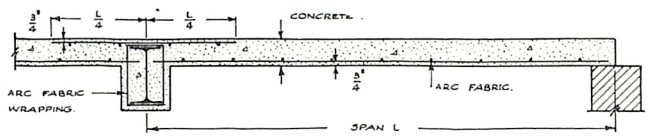
The tables in this handbook are compiled to assist in the use of A.R.C. Fabric under normal conditions of uniformally distributed loading. They have been prepared for continuous spans using a bending moment factor of $\frac{WL^2}{12}$ and are applicable to interior bays of a number of equal or approximately equal spans. This covers the conditions which most frequently arise

in practice of a slab supported on beams or walls. For slabs required to carry heavy concentrated loads, such as heavy machinery, walls, etc., special designs are necessary. If adjacent spans vary in length to an appreciable extent, or the loading is heavy or concentrated, it is necessary to make a more exact investigation of the bending moments.

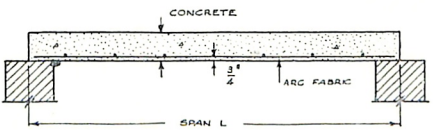
The fabric is laid $\frac{3}{4}$ inch up from the under-side of the concrete to provide for the positive moments, and separate short sheets extending to $\frac{1}{4}$ of the span each side of the interior support are placed $\frac{3}{4}$ inch down from the top of the slab to provide for the negative moments, as shown in Fig. 9 below.



CONTINUOUS SPAN



END SPAN



FREELY SUPPORTED SPAN

Fig. 9.

Various combinations of slab thicknesses and fabric are given, which will carry superimposed loads suitable for various purposes over a variety of spans.

The full factor of safety is provided on the weight of the concrete itself in addition to the load given at the top of each table, which is the safe superimposed load.

USE OF TABLES

The tables are for **continuous** spans. The figures in each table give the Ref. No. of A.R.C. Fabric to be used for the purpose of loading indicated at the head of the table. For instance, to carry a safe superimposed load of 200 lb. per square foot over a span of 9 feet using concrete 6 inches thick, No. 7 Fabric should be used. No. 7 Fabric has 3 gauge main wires at 3 in. cts. and 3 gauge cross wires at 12 in. cts. If the thickness of concrete is not determined by other considerations, it is most economical to select the size of fabric immediately below the heavy line and use the corresponding thickness of concrete shown in the left-hand column. The thickness of floor slab should not be less than 1/30th of the span.

End spans should, if possible, be made equal to, or less than, 9/10ths of the continuous spans. The same size of reinforcement will then suit. If the end spans are the same as the others, they may be designed from the tables by assuming them to be equivalent to a continuous span 10 per cent. greater.

A **freely supported** span may be designed from the tables, by assuming it to be the equivalent to a continuous span 25 per cent. greater, e.g., the reinforcement for a freely supported span of 8 feet would be the same as for a continuous span of 10 feet.

The nature of the support, i.e., whether it is a concrete beam, steel beam, or brick wall, does not affect the strength of the slab.

In every case, the weight of the floor slab has been allowed for in the tables.

SAFE WORKING STRESSES

The maximum working stresses allowed in these tables are:

800 lb. per sq. inch compression in the concrete.

25,000 lb. per sq. inch tension in the steel.

FLOOR SLAB TABLES

FOR CONTINUOUS SPANS

DWELLINGS, FLATS, SCHOOLS AND CHURCHES

Safe superimposed load
40 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No.
4	14	12	10	10	9			
4½	14	12	12	10	9	8		
5	14	12	12	10	10	9	8	7
5½	14	14	12	10	10	9	8	7
6	14	14	12	12	10	9	9	8
6½				12	10	10	9	8
7					10	10	9	8
7½						10	9	8
8								

ROOFS AND OFFICES

Safe superimposed load
50 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No.
4	14	12	10	10	9			
4½	14	12	10	10	8	8		
5	14	12	12	10	9	8	7	6
5½	14	12	12	10	10	9	8	7
6	14	12	12	10	10	9	8	7
6½			12	10	10	9	8	7
7					10	9	8	8
7½					10	9	8	8
8							9	8

SCHOOLS, CHURCHES, AND DINING ROOMS

Safe superimposed load
60 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No.
4	12	12	10	9	8			
4½	14	12	10	10	9	7		
5	14	12	10	10	9	8	7	6
5½	14	12	12	10	9	8	7	6
6		12	12	10	10	9	8	7
6½		12	12	10	10	9	8	7
7			12	10	10	9	8	7
7½				10	10	9	8	7
8					10	9	8	8

CORRIDORS AND SCHOOL ASSEMBLY ROOMS

Safe superimposed load
80 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No.
4	12	10	9	8	7			
4½	12	10	10	9	8	7		
5	12	12	10	9	8	7	6	
5½	12	12	10	10	8	7	6	6
6	14	12	10	10	9	8	7	6
6½		12	10	10	9	8	7	6
7			12	10	9	8	7	6
7½				10	10	9	8	7
8					10	9	8	7

FLOOR SLAB TABLES

FOR CONTINUOUS SPANS

DANCE AND ASSEMBLY HALLS, RETAIL SHOPS AND FACTORIES

Safe superimposed load
100 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No.
4	12	10	9	7				
4½	12	10	9	8	7	6		
5	12	10	10	9	7	6	5	
5½	12	12	10	9	8	7	6	5
6		12	10	9	8	7	6	5
6½			10	10	8	7	6	6
7			10	10	9	8	7	6
7½					9	8	7	6
8						8	7	6

WAREHOUSES AND GARAGES

Safe superimposed load
150 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No
4	10	9	7					
4½	10	9	8	6				
5	10	10	8	7	6			
5½	12	10	9	8	6	5		
6	12	10	9	8	7	6	5	
6½	12	10	10	8	7	6	5	4
7		10	10	9	7	6	5	4
7½			10	9	8	7	6	5
8				9	8	7	6	5

WAREHOUSES

Safe superimposed load
200 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No	No.
4	9	7						
4½	10	8	7					
5	10	9	7	6				
5½	10	9	8	6	5			
6	10	9	8	7	6	4		
6½		10	9	7	6	5	4	
7		10	9	8	6	5	4	3
7½		10	9	8	7	6	5	4
8				8	7	6	5	4

WAREHOUSES

Safe superimposed load
250 lb. per square foot

Thickness of Concrete	SPAN IN FEET							
	6	7	8	9	10	11	12	13
(in.)	No.	No.	No.	No.	No.	No.	No.	No.
4	8							
4½	9	7						
5	9	8	6					
5½	10	8	7	5				
6	10	9	7	6	5			
6½	10	9	8	6	5	4		
7	10	9	8	7	5	4	3	
7½		10	8	7	6	5	4	2
8			9	7	6	5	4	3

CONCRETE SLAB DESIGN USING A.R.C. FABRIC

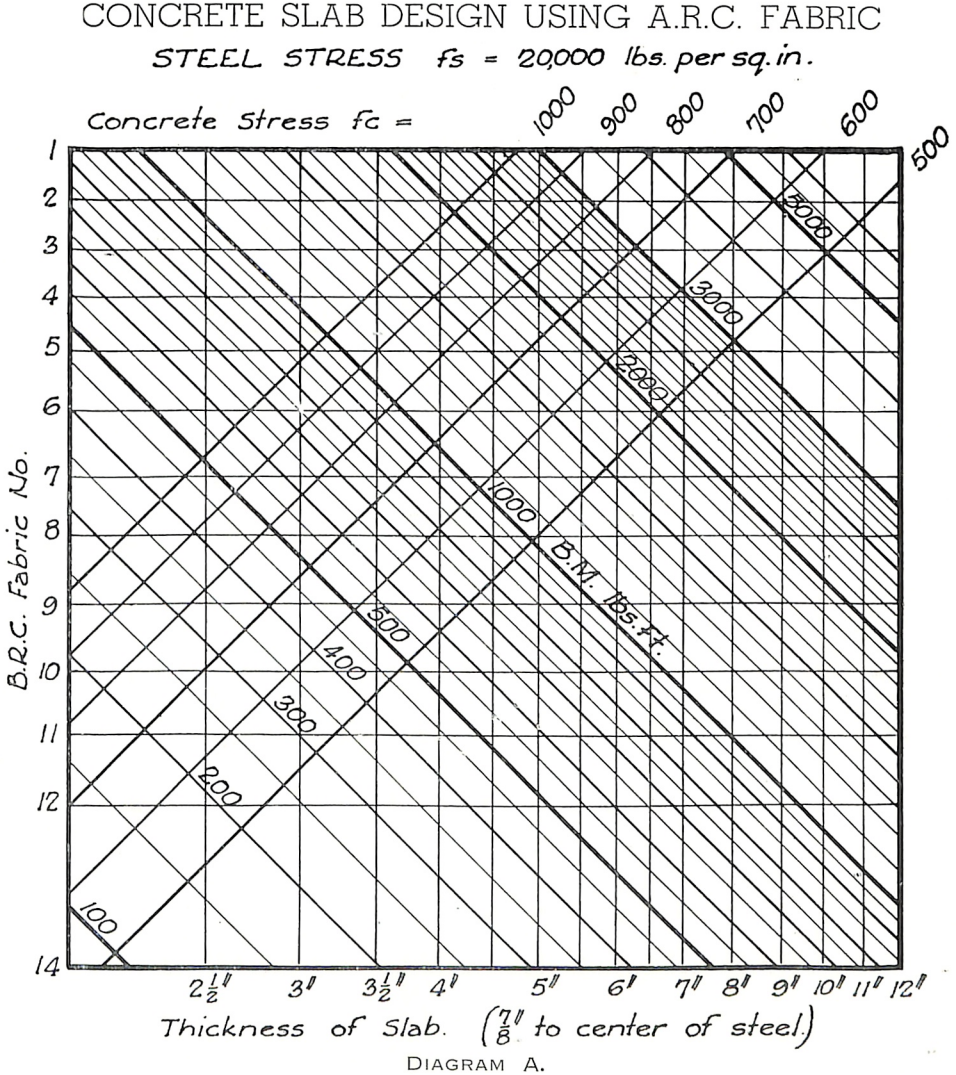


DIAGRAM A.

By the use of Diagrams A, B and C, slabs may be designed using steel stress of 20,000, 25,000 or 27,000 lbs. per square inch each in association with concrete stress of from 500 to 1,000 lbs. per sq. inch. Lines sloping downwards towards the right represent the bending moment per foot width of slab concerned, while lines sloping upwards towards the right represent concrete stress. The designer can see at a glance the extent to which a slight alteration in slab thickness will affect the concrete stress.

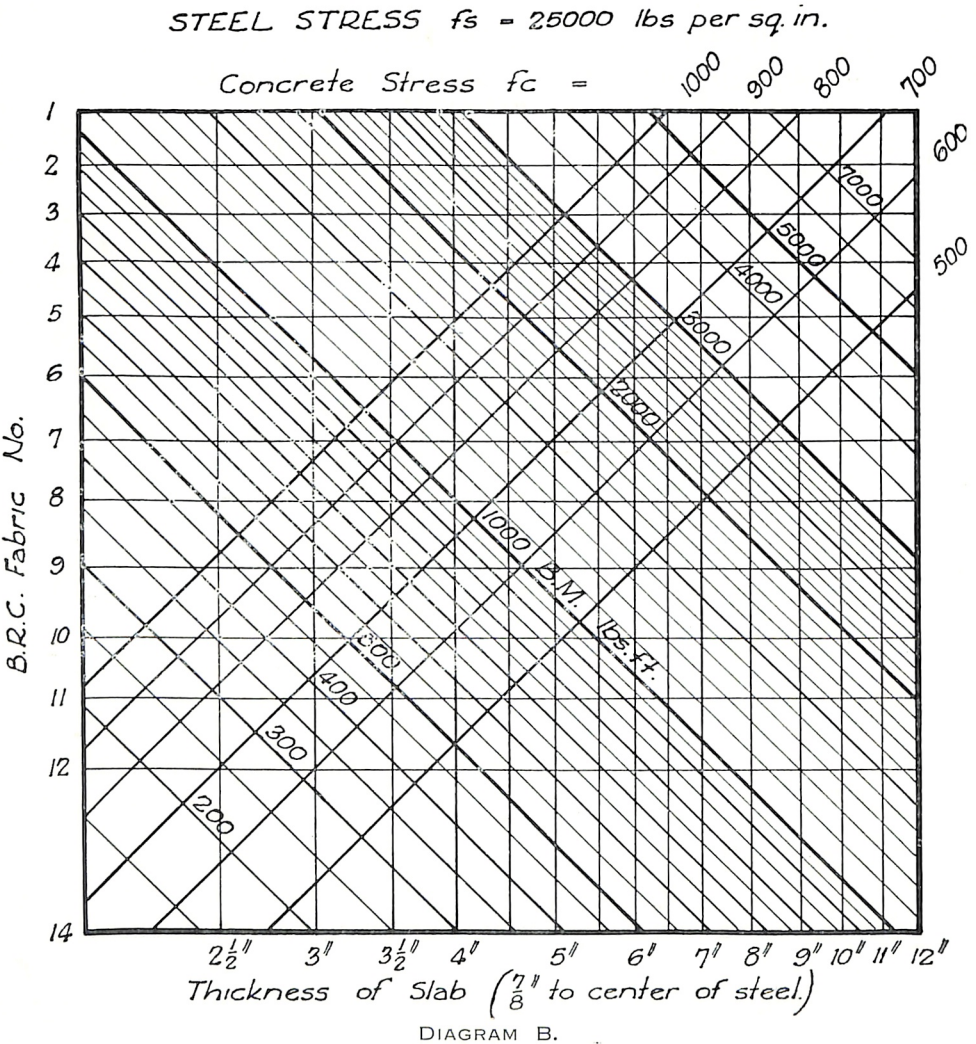


DIAGRAM B.

To design concrete slab, calculate in the usual manner the bending moment per foot width of slab, including that due to dead weight of slab itself according to the appropriate formulae and assumptions. Enter the diagram, corresponding to the steel stress employed, to a point showing the bending moment and also the desired working stress in concrete. From this point read downwards for the required slab thickness, and to the left for the corresponding A.R.C. fabric number. Fabric should be placed to give ¾ in. cover from the tension face of the concrete. In the preparation of these graphs the effective depth of slab has been assumed to be ⅞ in. less than the total slab thickness.

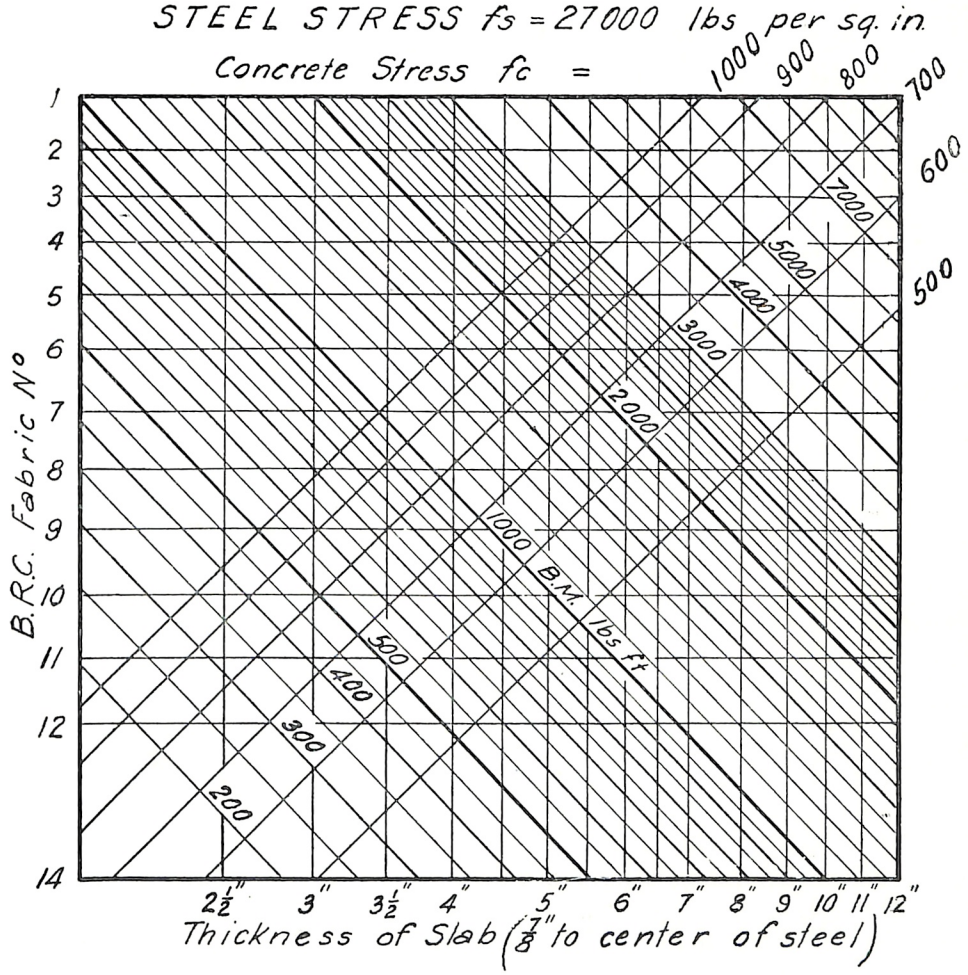


DIAGRAM C.

Slabs subjected to point loads are usually treated on the assumption that the isolated load is assumed distributed over a certain width of slab depending on the circumstances. Various conditions of "end fixing" of slabs may be considered in selection of appropriate formula for bending moment. Hence these graphs may be regarded as having a general application to all slabs for the working stresses covered, whatever the nature of the loading on the slab may be. Example: Concrete slab subjected to b.m. 1,500 ft. lb., using 25,000 lbs. per sq. inch fs and 700 lbs. per sq. in., fc would require a slab 5 in. thick and No. 7 A.R.C. fabric.

HOLLOW FLOORS

Hollow floors are suited for buildings such as hospitals, schools, hotels and flats where the live loads are light and it is desired to carry the floors over comparatively long spans without intermediate supporting beams. They are not suitable for heavy construction such as warehouses and industrial buildings. Generally, they are rather more expensive than beam and slab floors, although they have better insulation qualities. There are two main types, i.e., Hollow Block and Steel Trough Form. Each type consists of a series of small closely spaced concrete ribs, which are T beams, with a thin concrete slab on top, the space between the ribs being closed in at the bottom, thus providing hollows between floor and ceiling.

In the Hollow Block Floor, these hollows are formed by using a hollow cindcrete, terra cotta or gypsum block between the concrete ribs, the blocks being built in permanently as part of the floor, their under-sides forming the ceiling.

In the other type called a Steel Trough Floor, the hollows are formed by using shaped steel moulds between the concrete ribs, the moulds being removed after the concrete has hardened, and a false ceiling attached to the underside of the ribs.

With both types, if the ribs are supported on reinforced concrete beams, these beams may be designed as T beams if the flange thickness is increased to the required width by either stopping the blocks at the proper distance away from the stem of the beam, or using a shallower block on either side of the beam.

CHOICE OF TYPE

The hollow block floor is most suitable for small floors or for floors where the supporting beams are arranged irregularly. The blocks are usually about 18 inches wide by 9 inches long, and are thus conveniently small for fitting into areas of irregular shape.

The steel trough floor is most suitable for large areas of floor where the supporting beams are arranged regularly. The same forms can then be used over and over again and the construction is both speedy and economical. This effects a saving in freight charges, particularly for country work, when compared with hollow blocks.

HOLLOW BLOCK FLOOR

In this type, the ribs are spaced at from 1 ft. 10 in. to 2 ft. 6 in. centres, according to the width of rib required by

the design and the distance to be covered. Hollow terra cotta, gypsum, or cindcrete blocks are placed between the ribs with their soffits flush with the soffits of the ribs, giving a flat ceiling for plastering. Normally, if the concrete is allowed to thoroughly dry before plastering, no plaster stains will be visible under the ribs, but pattern stain may be minimised by using small facer tiles about ¾ in. thick in the bottom of each rib. Concrete is laid over the blocks for a thickness of from 2 in. to 3 in. depending on the design requirements. The reinforcements consist of steel bars in the ribs between blocks, suitably supported by A.R.C. Stirrups to give the correct concrete cover on the under-side, and a layer of A.R.C. Fabric, such as No. 688, in the slab over the blocks.

A table of suitable depths of floor for different loads and spans is given below. These blocks are the standard product of several manufacturers and can be obtained in depths ranging from 5 inches to 12 inches.

Open centering, consisting of a soffit board placed centrally under each rib and just wide enough to support the edges of the block, is the usual type of form work. The boards may be supported on cross joists at about 3 ft. to 4 ft. centres, which are in turn supported on struts about 4 ft. on centres.

HOLLOW BLOCK FLOORS

Suitable overall depths of floors for various loads and spans.

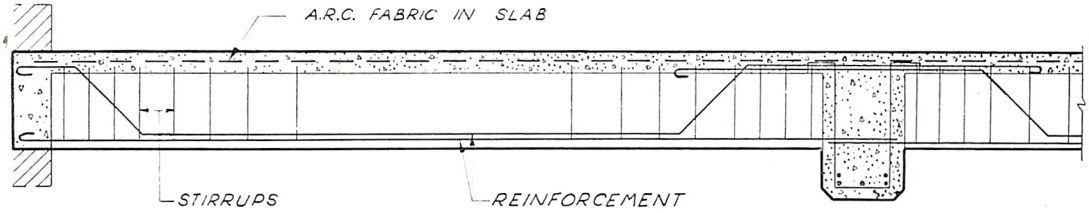
Superimposed Load	Span in Feet							
	8	10	12	14	16	18	20	22
40 lb. per sq. ft.	7½"	7½"	7½"	7½"	7½"	8½"	9½"	9½"
50 „ „ „ „	7½"	7½"	7½"	7½"	7½"	8½"	9½"	10½"
60 „ „ „ „	7½"	7½"	7½"	7½"	7½"	8½"	9½"	10½"
80 „ „ „ „	7½"	7½"	7½"	7½"	8½"	9½"	10½"	11½"
100 „ „ „ „	7½"	7½"	7½"	8½"	8½"	10½"	11½"	12½"
150 „ „ „ „	7½"	7½"	8½"	9½"	10½"	11½"	12½"	14½"

The depths shown are not necessarily the most economical, but may be assumed to be the minimum necessary for practical reasons. The weights of the different types of blocks vary considerably, but the table is based on the heaviest block in common use—cindcrete—with 5 in. minimum depth of available block and 2½ in. concrete over the blocks.

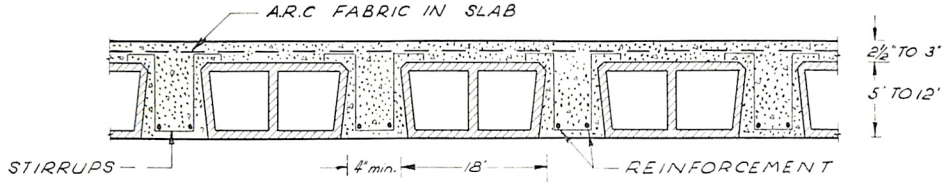
STEEL TROUGH FORM

When steel forms are used, the supporting form-work is very similar to that used for the hollow block type. The forms are made in lengths of 4 feet and 6 feet by 2 feet $1\frac{1}{2}$ inches wide at the bottom, and in depths ranging from 8 inches to 12 inches. The slab thickness is usually $2\frac{1}{2}$ to 4 inches.

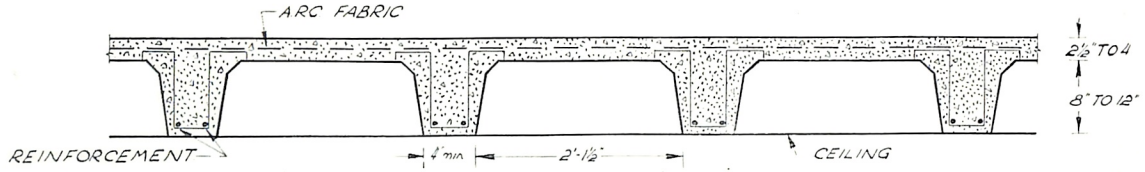
A timber strip is bedded in the bottom of each rib for attachment of the ceiling, which may be fibrous plaster, etc. The ribs and slab are reinforced similarly to the hollow block floor.



TYPICAL ELEVATION OF RIB



CROSS SECTION HOLLOW BLOCK FLOOR



CROSS SECTION STEEL TROUGH FLOOR

Fig. 10.

FLOORS ON THE GROUND

Various A.R.C. Fabrics are made for use in slabs laid directly on the ground, either excavated or filled. Examples of such slabs are the extensive floors in the modern type of single storey factory, office, factory and warehouse basements, platforms, garages, floors of tanks and swimming pools, paths and roads. Roads offer special problems and are dealt with later on pages 119 to 128.

Unless the ground slab is laid on solid sub-soil, it is advisable to reinforce it with A.R.C. Fabric. Whilst examples can be shown of un-reinforced floors laid on the solid which have not cracked, these are exceptions and it can usually be found that the quality of the concrete was exceptionally good. Unless careful supervision is given, concrete is usually mixed slightly on the wet side, giving rise to greater shrinkage, which will inevitably cause cracks unless reinforcement is provided to reduce what might have been unsightly cracks, to a large number of cracks so fine as to be invisible and harmless.

The use of A.R.C. Fabric in ground slabs not only increases the strength, but also reduces the cost of the floor by enabling a thinner slab to be used. The thickness of concrete is determined by the nature of the ground, and the purpose and loads for which the floor is required. The thickness depends on the bending strength of the slab and whatever thickness of plain concrete is sufficient, it is always possible to use a thinner slab reinforced with A.R.C. Fabric, the cost of the fabric being more than offset by the saving in concrete.

Floors laid on filled ground without reinforcement invariably crack. Cracking is caused by shrinkage of the concrete during setting, restriction of free expansion and contraction due to temperature changes, unequal settlements, or unequal loading. If the floor is finished with a surfacing of granolithic or other form of paving, the cracking may extend to the surface. In some cases it causes serious trouble; in all cases it is unsightly and objectionable. The liability to cracking is greatly reduced and in most cases eliminated by using a layer of A.R.C. Fabric in the concrete. Usually, the slab can be made from 4 in. to 6 in. thick, and it should be remembered that a 4 in. slab reinforced with No. 655 A.R.C. is in many ways stronger than a plain concrete floor 6 in. thick. Where the ground is particularly bad or the loading unusually heavy, thicker floors and heavier reinforcement may be necessary. It is impossible to lay down any rules for the thickness and gauge of Fabric

required, and we recommend that the services of our engineering department be utilised in order to obtain the best advice.

The usual construction is to lay the floor in approximately square panels, the size of panel being arranged to suit the dimensions of the floor, and reinforced with a square mesh fabric laid 1 in. from the bottom. As a rule, the size of panel should not-exceed 800 square feet, but when the ground is filling or the loading heavy, smaller panels are advisable.

The joints between panels are often made as dry joints, but it is an advantage to use a mastic compound to seal the joint and give some freedom for expansion. The reinforcement should be continuous through the joints, but in some cases it is preferable to stop the reinforcement at the joints and use dowel bars across the joint 1 in. from the top of the slab.

Light gauges of fabric such as No. 610 and 688 A.R.C. may be conveniently laid from standard rolls, but heavier gauges such as Nos. 611, 622 and possibly 655 A.R.C. are best used in flat sheets.

In all cases, it is desirable to lay building paper or use other means to prevent leakage of cement paste and to keep the reinforcement clean. Otherwise, the ground should be well moistened before placing the concrete.

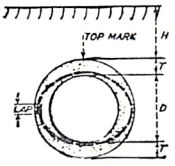
CULVERTS

Reinforced concrete, either in the form of precast pipe or in-situ work, is practically the only material now used in the construction of culverts. Precast pipes are suitable for small culverts, and a number of firms manufacture this type of product.

In situ culverts should be reinforced with A.R.C. Fabric, and the table on page 78 shows concrete thicknesses and fabric required for various sizes of culverts. The strength of the culvert is governed by the depth below the surface and the total loading it will have to carry. The tables allow for British Ministry of Transport loading for main roads.

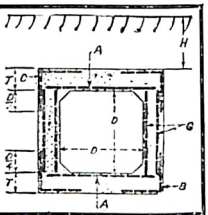
CULVERTS

TYPE 1
PIPE
CULVERTS
2 laps if desired



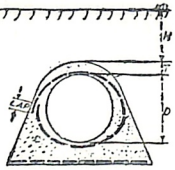
D Dia. of pipe	H Depth below ground level	T Thick-ness of concrete	Lap	Rein-force-ment A.R.C. Fabric
2' 0"	2' 0"	3"	15"	No. 12
	3' 0"	3"	15"	No. 12
	5' 0"	3"	15"	No. 12
	7' 6"	3"	15"	No. 12
	10' 0"	3"	15"	No. 12
3' 0"	2' 0"	4"	15"	No. 10
	3' 0"	4"	15"	No. 10
	5' 0"	4"	15"	No. 12
	7' 6"	4"	15"	No. 12
	10' 0"	4"	15"	No. 12
4' 0"	2' 0"	5"	15"	No. 8
	3' 0"	5"	15"	No. 8
	5' 0"	5"	15"	No. 10
	7' 6"	5"	15"	No. 10
	10' 0"	5"	15"	No. 10
5' 0"	2' 0"	6"	20"	No. 6
	3' 0"	6"	20"	No. 6
	5' 0"	6"	15"	No. 8
	7' 6"	6"	15"	No. 8
	10' 0"	6"	15"	No. 8
6' 0"	2' 0"	7"	20"	No. 6
	3' 0"	7"	20"	No. 6
	5' 0"	7"	20"	No. 6
	7' 6"	7"	15"	No. 8
	10' 0"	7"	15"	No. 8

TYPE 2
BOX
CULVERTS
(Square section)



D Size of culvert	H Depth below ground level	T Thick-ness of concrete	Reinforcement A.R.C. Fabric	
			Sheets A and B	Sheet C
4' 0" × 4' 0"	2' 0"	5"	No. 6	No. 12
	3' 0"	5"	No. 6	No. 12
	5' 0"	5"	No. 8	No. 12
	7' 6"	5"	No. 6	No. 12
	10' 0"	5'	No. 6	No. 12
5' 0" × 5' 0"	2' 0"	6"	No. 5	No. 12
	3' 0"	6"	No. 6	No. 12
	5' 0"	6"	No. 6	No. 12
	7' 6"	6"	No. 5	No. 12
	10' 0"	6"	No. 4	No. 12
6' 0" × 6' 0"	2' 0"	7"	No. 4	No. 10
	3' 0"	7"	No. 5	No. 12
	5' 0"	7"	No. 5	No. 12
	7' 6"	7"	No. 4	No. 12
	10' 0"	7"	No. 3	No. 12
7' 0" × 7' 0"	2' 0"	8"	No. 3	No. 10
	3' 0"	8"	No. 4	No. 12
	5' 0"	8"	No. 4	No. 12
	7' 6"	8"	No. 3	No. 12
	10' 0"	8"	No. 1	No. 12
8' 0" × 8' 0"	2' 0"	9"	No. 1	No. 10
	3' 0"	9"	No. 2	No. 12
	5' 0"	9"	No. 3	No. 12
	7' 6"	9"	No. 2	No. 12
	10' 0"	10"	No. 1	No. 12

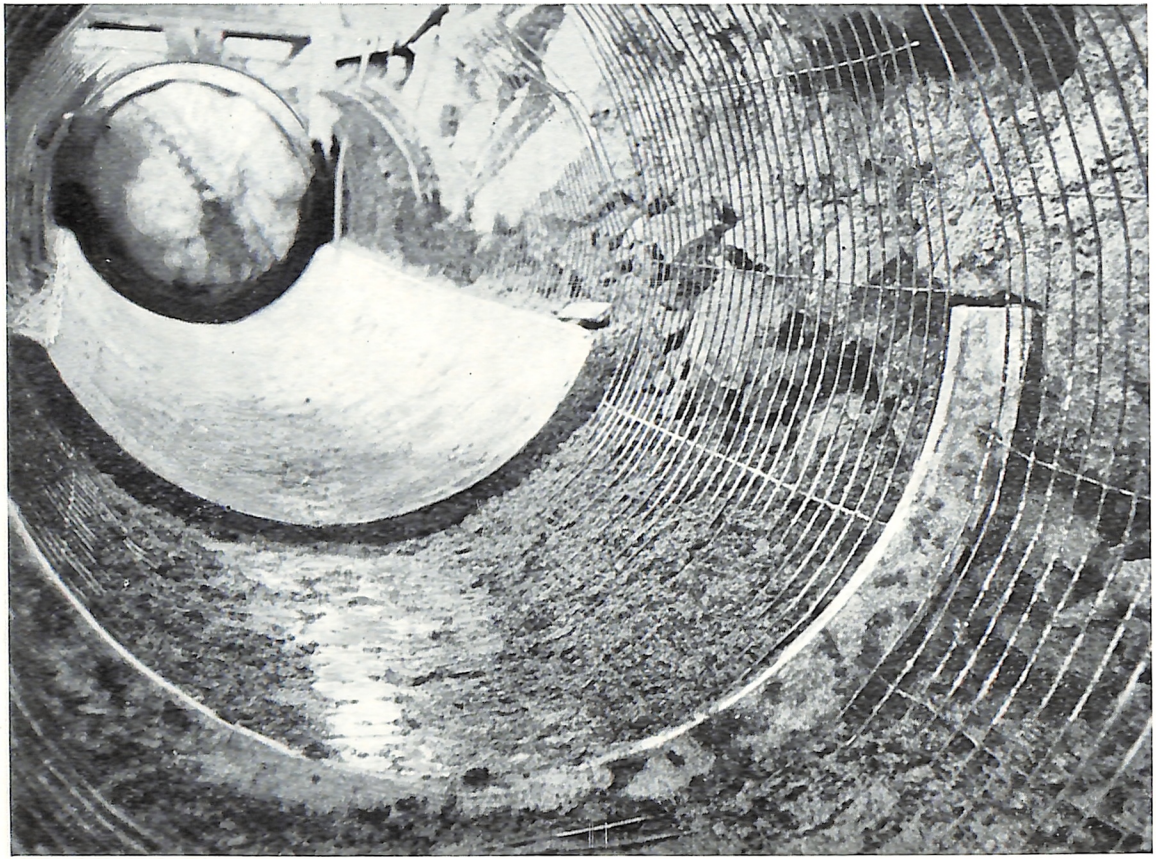
TYPE 3
To be used where foundations are poor



ARCH CULVERTS
Extra layer of Fabric laid longitudinally in bottom

Reference No. of A.R.C. Fabric and thickness of concrete ring similar to Type 1.

Above designed to carry Ministry of Transport Loading
Ground assumed solid and not saturated
Ground assumed to weigh approximately 100 lb. per cu. ft. Angle of repose 35°



CIRCULAR STORM WATER DRAIN REINFORCED WITH A.R.C. FABRIC

REINFORCED CONCRETE WALLS

PANEL WALLS

Generally, the external walls of a reinforced concrete frame building are supported at each floor by the frame members, and carry only their own weight. Such walls are termed panel or curtain walls. They may be constructed of various suitable materials, such as concrete, brick or concrete block. The thickness depends upon the material, type of construction, and local building regulations.

If concrete panel walls are used, the exterior walls are normally made 6 inches in thickness. A.R.C. Fabric No. 611 is the ideal reinforcement for these walls, and can be supplied in flat sheets of suitable length to run from floor to floor levels. The cost of placing these sheets is only a fraction of the cost of spacing and wiring the large number of rods in the usual alternative specification of $\frac{3}{8}$ inch diameter rods at $7\frac{1}{2}$ inch centres both ways.

For walls 8 inches or more in thickness, it is accepted practice to reinforce the wall with a layer of reinforcement on each face, and we recommend two layers of No. 622 A.R.C.

Internal panel walls of reinforced concrete are usually made 4 inches thick, the recommended A.R.C. Fabric is No. 655, which can be supplied in flat sheets of suitable size.

BEARING WALLS

A bearing wall is defined as a wall which carries any vertical load in addition to its own weight. If constructed of reinforced concrete, the thickness should be not less than 1/25th of the unsupported height. For concentrated loads, the length of wall to be considered as effective for each shall not exceed the centre to centre distance between loads, nor 4 times the wall thickness plus the width of bearing. The reinforcement should not be less than the reinforcement specified for panel walls, but where vertical loads are to be supported, additional vertical reinforcement may be necessary.

In all reinforced concrete walls, it is advisable to provide additional reinforcement around all sides of door and window openings to prevent cracking.

In addition to the recommended A.R.C. Fabric, a $\frac{3}{8}$ in. or $\frac{1}{2}$ in. diameter rod about 3 ft. longer than the opening should be placed on each side, with an extra bar 3 ft. long placed diagonally at each corner.

COLUMN AND GIRDER WRAPPING

Steel columns and steel beams have very little resistance to fire, and in buildings where they are used, it is usually necessary to encase them in concrete to protect them. This covering of concrete will "spall" when heated, and at times even without the application of heat, unless it is efficiently bound with steel reinforcement.

The SAA Code calls for a minimum fire protection to structural steel columns of 3 in., and to steel beams 2 in. of concrete. The most effective way of providing this is to encase the steel work in the necessary thickness of 1 : 2 : 4 concrete reinforced with No. 14 A.R.C. Fabric wrapping, 3 in. x 12 in. mesh. The wrapping provides a most effective bond together with accurate spacing; the wires being rigidly held together are not easily displaced as is the case when 8 gauge black wire is wound on by hand.

It is supplied in sheets accurately bent to enclose the column or beam with the wires at 3 in. centres running around

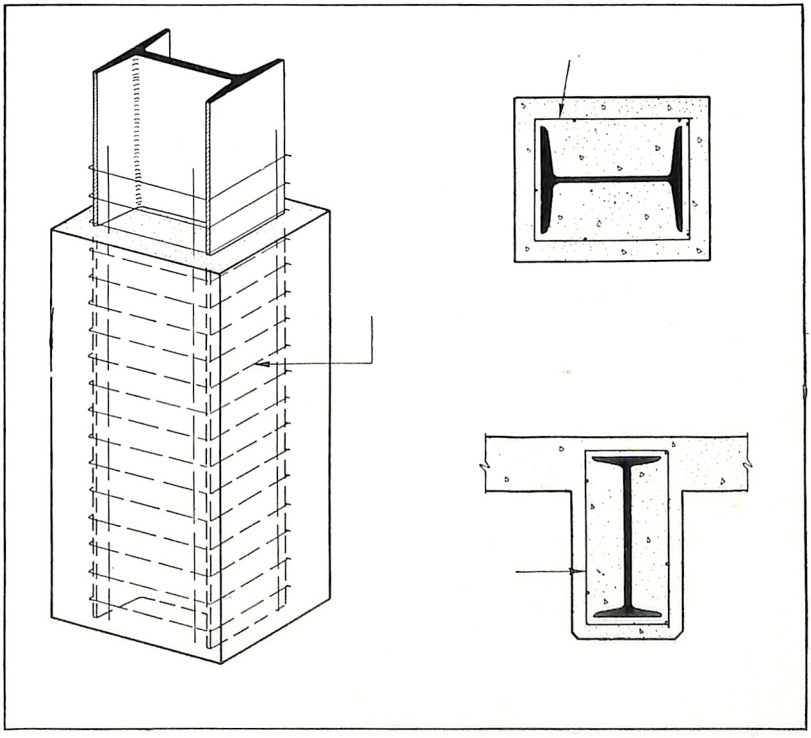
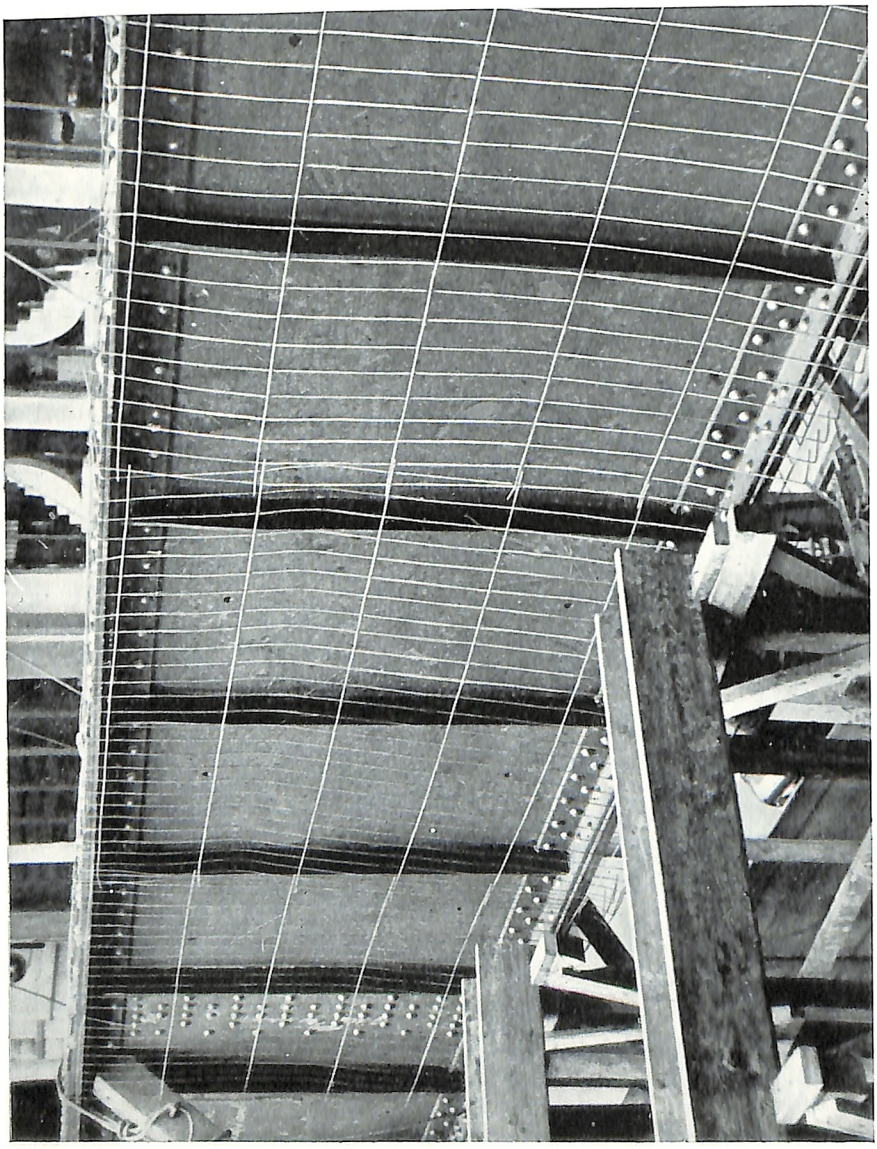


Fig. 11

the steel section. The standard width of the sheets is 7 ft., and they are easily placed in position on the steel work by springing open one end.

The use of these wrappings is shown in the accompanying illustrations.



TYPICAL A.R.C. GIRDER WRAPPING

A.R.C. BRICK WORK REINFORCEMENT

Reinforced brick work is, in reality, a form of reinforced concrete in which the irregular stone aggregate is replaced by a regular shape aggregate in the form of bricks. It is less allied to ordinary brick work than it is to reinforced concrete, and its strength can be calculated in the same way as that of the latter.

STRENGTH

A reinforced brick wall will withstand horizontal pressure from either side, such as that of the wind or of material piled against the wall, and will also, acting as a vertical beam, carry its own weight from pier to pier.

The additional strength which reinforcement gives to a brick wall is such that a 4½ inch wall, for instance, may be used in panels about 18 ft. long between buttresses or other supports. If used as a boundary wall or an outer wall of a building and reinforced with A.R.C. brick reinforcement, it will then be sufficiently strong to withstand normal wind pressures. A wall of this kind is suitable for a small garage or similar outhouse and, at the same time, it will support the roof. The accompanying photographs show tests of a 4½-inch brick panel reinforced with A.R.C. Fabric in the mortar joints. The panel consists of 5 courses. In one view (Fig. 12), it is shown as a vertical cantilever, carrying its own weight, projecting rather more than 8 ft. beyond the nearest support, and in the other view (Fig. 13) it is turned over on its side and tested as a slab carrying a superimposed load, in addition to its own weight, of 16 cwt., between supports 7 ft. apart.

ECONOMY

It will be evident that this type of wall is more economical than an unreinforced brick wall, which would have to be 9 inches or 13½ inches thick. There is also the advantage that the reinforced wall is a vertical girder sufficiently strong to carry its own weight over the length from buttress to buttress,

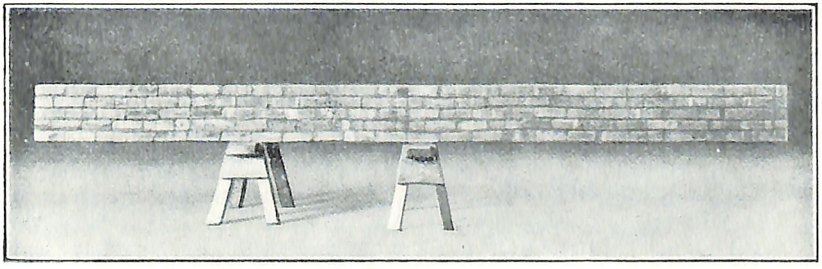


Fig. 12.

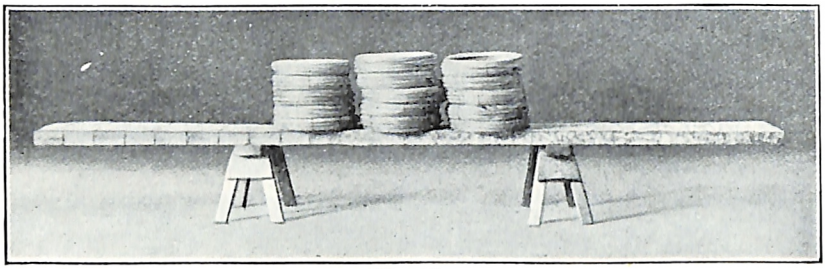


Fig. 13.

and requires no other foundation. This is an advantage that may be made use of in existing buildings if a partition wall is required in a position where there is no supporting girder. In localities where bricks are readily obtainable at a reasonable price, reinforced brick work is a more economical and a more quickly built form of construction for panel walls than reinforced concrete.

APPLICATION

As the object of reinforcement is, in most cases, to provide tensile strength for the resistance of lateral pressure against the brick work, the best position for the reinforcement is as close as possible to the faces of the brick work, where it performs its best duty. In substituting reinforced brick work for plain brick work, it should be borne in mind that a sufficient area of brick work must be provided to carry the compressive loads, such as might be transmitted to the walls from the floors resting on them, although such cases are hardly likely to arise in connection with panel and partition walls, and the point is generally negligible.

The walls should be built with cement mortar in the proportions of 1 part cement to 3 parts sand and 1/10th part lime, and it is just as necessary to use cement for the mortar as it is necessary to use cement in reinforced concrete.

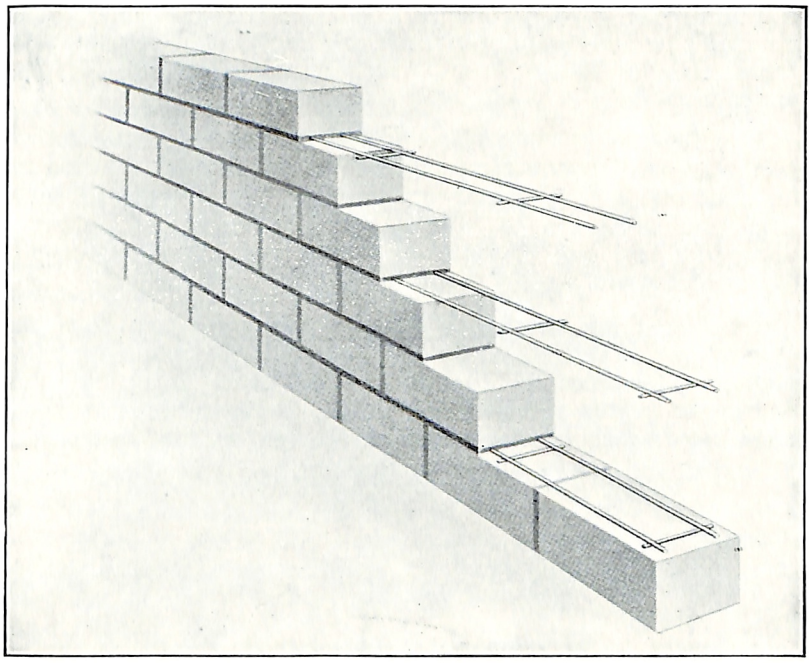
Sufficient cement mortar should be used to fill the joints, and the bricks should be moistened so that they will not absorb from the mortar the moisture which is needed to ensure proper setting. The reinforcement should be put in every 4th, 3rd or 2nd course, or, for maximum strength, in every course, depending on the length of the wall and the purpose it is to fulfil.

PARTICULARS OF A.R.C. BRICK REINFORCEMENT

A.R.C. brick reinforcement is made from 12 gauge galvanised wire having a breaking strength of approximately 35 tons per square inch.

For 4½-inch walls, the mesh consists of 2 strands of wire 2 inches apart with cross wires welded to them at intervals of 12 inches.

For 9-inch walls, the mesh consists of 4 strands of wire 2 inches apart, with cross wires every 12 inches.



The reinforcement is stocked in rolls 80 ft. long and is easy to manipulate.

Reference No.	Thickness of wall (in.)	Width of fabric (in.)	No. of Wires	Weight per roll (lb.)
B1	4½	2	2	5.1
B2	9	6	4	10.5
B3	13½	10	6	15.8
B4	18	14	8	21.2
B5	22½	18	10	26.6
B6	27	22	12	31.9

PRESTRESSED CONCRETE

The recent development of prestressed concrete has introduced a new technique of interest, whereby initial compressive stresses are introduced in a concrete member to counteract the tensile stresses produced by the loads.

The steel in prestressed concrete is not used as reinforcement, but as a means of producing this compressive stress in the concrete, and is usually in the form of cold drawn high tensile wires having an ultimate tensile strength of between ninety-five and one hundred and fifty tons per square inch, and of diameters usually between .276 and .08 inches.

The wires are tensioned using suitable devices, and this tensile force is applied to the concrete member, inducing as a reaction, compressive stresses of sufficient magnitude to entirely or nearly eliminate the tensile stresses resulting from loads causing a bending or direct tension on the section.

Due to creep and shrinkage, approximately 10-20 per cent. of the initial prestress may be lost, but this can be allowed for in the calculations.

The two methods of prestressing in general use are as follows :—

1. PRE-TENSIONING

In this method, the wires are tensioned between end anchorages before the concrete is cast around them, and the tension released after the concrete has sufficiently hardened. The prestress is thus retained by bond between the steel and the concrete, small diameter wires — usually between .08 and .2 in. — being used to increase the bond. This system is most suitable for use under factory manufacturing conditions, and is used for the "long-line" system in which a number of units are produced at the one time, although it may be used for individual units.

2. POST-TENSIONING

With this method, the concrete is cast and allowed to harden before the prestress is applied. Suitable holes are left in the concrete through which the wires are threaded after the

concrete has hardened. These holes can be made by embedding inflatable rubber cores which are removed after the concrete starts to set. Sometimes the wires are cast into the concrete and prevented from bonding by various means such as an enclosing sheath. The wires are then stressed against the ends of the member and securely anchored at the ends by special wedges. They may afterwards be grouted in for protection against corrosion, and also to give the extra safeguard of bond between the concrete and steel. The diameter of wire normally used is between .2 and .276 in., and the two main anchorage systems commonly used are those devised by M. Freyssinet and M. Magnel, although other types such as the Lee-McCall System are in use.

The Freyssinet type consists of a male and female cone of very high strength, both made of aluminous cement and having strong circumferential reinforcement. Using these cones, twelve wires can be anchored simultaneously.

Special steel "sandwich" plates and wedges, which enable two wires to be anchored at the one time, are used in the Magnel system.

The Lee-McCall system uses high tensile alloy steel bars with the ends having special threads and nuts which develop the full strength of the unthreaded part of the bar.

In these systems, the tensioning is applied by means of hydraulic jacks bearing against the ends of the member, and the prestress can thus be accurately applied.

Post-tensioning is suitable for on-site work where the members can be cast either in their proper positions or on a casting bed to be lifted into position after stressing.

Although the technique of prestressing enlarges the scope and adaptability of concrete as a structural medium, it cannot be regarded in every case as an alternative form of construction to normal reinforced concrete.

To be fully effective, prestressed concrete requires materials and workmanship of exceptional quality, with the concrete having a twenty-eight day cylinder strength of the order of 5,000-7,000 lb. per square inch, and up to 9,000 lb. per square inch for highly stressed work. The technique requires continuous skilled supervision to ensure accurate control of the concrete strength and the tensioning of the high tensile wires. Under suitable conditions, prestressing results in a large reduction of the weight of steel as well as reduced concrete quantities. On the other hand, the saving is offset to consider-

able extent by the increased unit cost of the high quality steel and concrete, and the cost of the anchorages, jacks, and other equipment. The current price of this steel if of Australian manufacture is approximately double that of cold drawn wire as used in A.R.C. fabrics, and considerably more again if of overseas origin.

The system is very suitable where shallow members are required such as in bridge work or for long span precast beams, and also for liquid-retaining structures. The circular tank is particularly suitable for pre-stressing, either by using a patented continuous system of winding or by a series of co-ordinated segmental operations.

Generally, as the magnitude of the construction increases, the cost of prestressing decreases; on the one hand, in proportion to the size of the units, and on the other hand, proportionally to the number of similar repetitive members required.

Where a prestressed design is warranted by considerations of overall economy and convenience, its use would be recommended, and we have the technical staff available to carry out such a design.

CONCRETE MIXTURES AND GENERAL CONSTRUCTIONAL WORK

GENERAL NOTES

The necessary characteristics of the various ingredients have been dealt with previously, but it is still of vital importance that the proportioning, mixing, placing and curing of the concrete be properly carried out.

The principal requirements of the hardened concrete are strength and durability, and the design of the mixture is influenced by considerations of economy and workability. A successful design will achieve a proper balance between these four essentials.

The mixture should be placeable and make economical use of the available materials, and when hardened, should have the necessary strength and durability to resist exposure to the specific design conditions. The principal factors determining the strength are the proportion of cement, the proportion of water, and the grading and cleanliness of the aggregates. The strength of concrete increases as the water-cement ratio decreases, providing that the mixture is sufficiently workable to allow proper compaction. The strength also increases as the proportion of cement increases, mainly on account of the reduction in the water-cement ratio made possible by the increased workability of richer mixes, but generally, excessive cement causes greater shrinkage. Insufficient water reduces the workability, thereby making it impossible to properly consolidate the concrete.

Vibratory consolidation in itself does not affect the strength of the concrete, but it enables concrete with low water content to be properly compacted, thereby producing stronger concrete because workability is obtained with a lower water-cement ratio.

PROPORTIONING

Preferably, measurement of all the materials should be by weight, but the cement at least should be so determined. The standard bag of cement weighing 94 lbs. is a convenient unit on which to base the weights of water and aggregates. Generally, however, in Australia, it is still the practice to measure the aggregates by volume and the cement by weight, using the standard 94 lb. of cement — assumed as 1 cubic foot in volume — as the basis, and the volume of coarse aggregate is twice the volume of fine aggregate for arbitrary proportioning.

Tests indicate that, except in mixtures of 1 : $1\frac{3}{4}$: $3\frac{1}{2}$ and richer, such proportions, when used with $\frac{3}{4}$ inch aggregate, do not always result in a dense workable concrete, especially if crushed stone is used.

As the strongest concrete is usually the densest, the best result is seldom obtained by such arbitrary proportioning, and the actual proportions of fine and coarse aggregate should be related to the grading of the materials and their void contents. It is normally recommended that the proportions of fine to coarse should be between 1 : $1\frac{1}{2}$ and 1 : $2\frac{1}{2}$, but for major works, it is desirable to make tests to determine what proportions of cement, fine and coarse aggregates will give a sound, dense, and workable concrete of the strength required.

The following mixtures are commonly used in reinforced concrete construction :—

	Cement	Fine Aggregate Cubic Feet	Coarse Aggregate Cubic Feet
(a)	94 lbs.	2	4
(b)	94 lbs.	$1\frac{2}{3}$	$3\frac{1}{3}$
(c)	94 lbs.	$1\frac{1}{2}$	3
(d)	94 lbs.	1	2

With cement obtainable in 94 lb. bags, the above proportions enable at least one full bag to be used at a time, and the mixer should be of suitable capacity so that it is not necessary to split a bag.

1 : 2 : 4 mix is commonly used for normal construction.

1 : 1 : 2 is used only occasionally in columns which are required to have a minimum size, and economy is not an

essential factor. The two intermediate proportions — b and c — are often used in water-retaining structures, etc., where an impervious concrete is required. A leaner mix than those given may often be used for mass concrete work.

BULKING OF SAND

The quantity of sand given in the table assumes dry material, but the sand on the job is seldom in this condition. Fully saturated sand has the same volume as dry sand, but in any intermediate stage the volume is considerably increased. This is known as "bulking", which may be as much as 40 per cent. with fine sand containing 5 per cent. moisture by weight, and the finer the sand, the greater the increase in volume. This bulking must be allowed for so as to obtain the true volume of equivalent dry sand, otherwise the mix will be under-sanded and honeycombed concrete will be produced.

The percentage "bulking" of sand can be found, as previously mentioned, on page 35, by the use of simple apparatus.

A measuring cylinder is half-filled with sand, without packing it; the cylinder is then three-quarter filled with water, and after shaking vigorously, the sand settles down to the same volume that it would occupy if perfectly dry.

The percentage bulking of the sand is represented by

$$\frac{\text{Apparent reduction in volume of the sand}}{\text{Final volume of the sand}} \times 100$$

Coarse aggregates are little affected in volume by moisture.

When tests for moisture cannot be made, approximate values may be based on the following table:

Very wet sand	$\frac{3}{4}$ to 1 gal. per cub. ft.
Moderately wet sand	about $\frac{1}{2}$ gal. ,, ,, ,,
Moist sand	about $\frac{1}{4}$ gal. ,, ,, ,,
Moist gravel or crushed rock	about $\frac{1}{4}$ gal. ,, ,, ,,

The coarser the aggregate, the less free water it will carry.

PROPORTION OF WATER TO CEMENT

It is most important to control the proportion of water, as the quantity used in mixing makes a great difference to the strength of the concrete after setting and hardening. A certain minimum proportion is necessary in order to hydrate the

cement, but this amount must be increased to make the concrete sufficiently workable to be placed by ordinary methods. Provided the concrete is sufficiently workable to be compacted by the method of placing used, its strength depends on the proportion of water to cement used; the greater the proportion of water, the weaker the concrete. Density, impermeability and, therefore, durability and subsequent shrinkage, are also adversely affected by excess water. It is difficult to specify the exact quantity required, as it varies according to the nature and moisture condition of the aggregates, and it should be determined by tests. It should be maintained constant unless the materials are changed, or the moisture in the sand varies. As a rough guide, for a 1 : 2 : 4 mix without using vibratory consolidation, the quantity of water required per 94 lb. bag of cement would vary between $5\frac{1}{4}$ and $6\frac{1}{4}$ gallons, depending on whether the sand is damp or dry.

SLUMP TEST

This is used as a measure of the consistency or "state of fluidity" of the wet concrete. It serves as a convenient practical method of checking the water content. The slump varies with the shape and grading of the aggregates, the proportion of cement to aggregate, and with the water content. For a given set of materials, the slump is an indication of the water content, but it should not be used to compare mixes of wholly different proportions or of different kinds of aggregates.

For example, if the same slump were obtained with two different mixtures, one made with rounded gravel and the other with angular crushed stone, the volume of mixing water would be greater in the case of the crushed stone, and the strength of this concrete would be correspondingly reduced.

The apparatus required is a truncated metal cone with open ends, the top diameter 4 in. and bottom diameter 8 in., and 12 in. high. It should be made of galvanised metal not less than 16 S.W.G. and the internal surface must be smooth. Suitable lifting handles and foot pieces should be provided, as shown in the sketch on page 93.

The cone is placed on a flat surface such as a smooth board, large end downward, and is held firmly in place by standing on the foot pieces while filling it with concrete. The concrete is placed in three layers each of approximately equal volume. Each layer must be punned 25 times with a $\frac{5}{8}$ in. diameter rod about 2 ft. long and bullet shaped at the lower end. The cone is then lifted vertically, leaving the concrete on the board. The slump is measured by the decrease in height of the concrete.

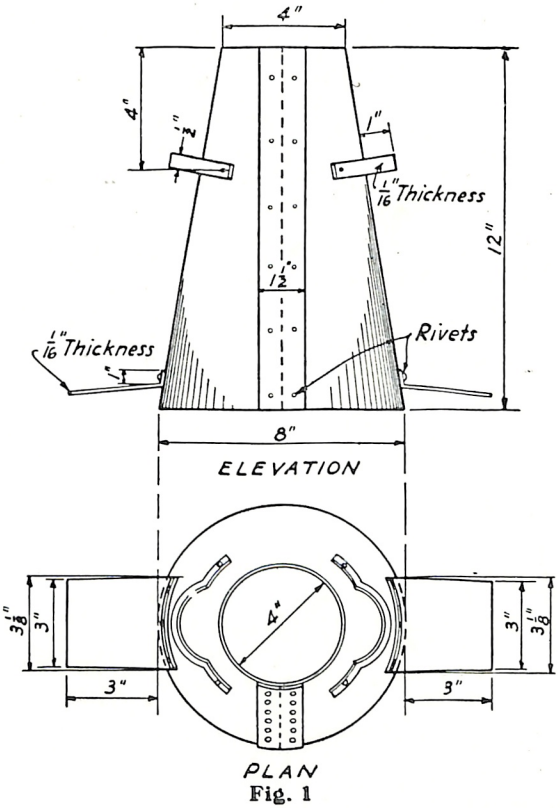


Fig. 1

Once the right slump has been obtained, tests should be made periodically each day whilst concreting is in progress, to ensure that there is no major variation. The slump to be used depends upon the type of work, and the following figures will serve as a guide:

Footings	3" slump
Columns	4" "
Walls	5" "
Beams	4" "
Floor slabs	4" "
Impermeable work	4½" "

Where vibratory consolidation is used, these figures should be considerably reduced, to avoid segregation.

MEASUREMENT OF MATERIAL

Accurate measurement of all the ingredients used in concrete is necessary for the production of uniform batches of a given quality and for the most economical results. The material should not be measured haphazardly with shovels. The quantities of fine and coarse aggregates should be measured in gauge boxes, and a box is necessary for the cement unless using a full bag batch. If bottomless boxes are used, there is a risk of losses and contamination after measuring when shovelling the materials into the mixer.

For large jobs, it is preferable to install a weight batching plant so that all the materials can be accurately measured by weight. In this case, no account need be taken of the bulking factor, and the only correction necessary is for the weight of moisture in the aggregates. As this cannot exceed 5 per cent., it may usually be neglected. Where the measurement is made by volume, the allowance for bulking must be made.

Proper control of the mixing water is essential, and the amount of water is regulated to give the water-cement ratio required, to produce the concrete strength specified with the necessary workability. In many concrete mixers, the amount of water is controlled by an automatic gauge.

The water-cement ratio is the ratio of the weight of water, including the weight of water in the aggregates, to the weight of cement used in a batch. When mechanical vibrators are properly used, it is often possible to produce dense concrete of high strength using a water-cement ratio of less than .45.

MIXING

Practically all concrete, even for small jobs, is mixed by machine. The mixer should never be loaded above its rated capacity, as overloading prevents thorough mixing. The mixing should be continued for a period of one to two minutes after all the materials, including the water, are in the drum. Thorough mixing gives increased workability, and also assists in producing watertight concrete.

Hand mixing should not be permitted, except for unimportant work requiring small quantities of concrete. Where hand mixing is used, it is usual to specify that the quantity of cement be increased by 10 per cent. The materials should be mixed on a smooth close boarded platform. The coarse aggregate is measured out and tipped on to the platform, the fine aggregate

is spread in a layer on top of the coarse, and the cement spread out uniformly on top.

Turn the heap over twice dry, and about three times while the water is being added. The water should be applied through a rose on a measuring can, taking care to avoid loss of cement by preventing the water running off, and the mixing continued until the mass is uniform in colour and consistency.

STORAGE OF CEMENT

The cement should be stored in a watertight shed having a floor raised off the ground to permit air circulation underneath. Sometimes the cement in the bottom layer of bags becomes caked due to pressure. Such material may be used after breaking up to powder. If the caking is due to dampness, the cement will not break into powder, and in this event, it must not be used.

PLACING

Before placing concrete, all sawdust, chippings, nails and other debris should be removed from the places to be occupied by the concrete, and the forms should be thoroughly wetted — except in freezing weather — or oiled. Where practicable, the concrete should be placed directly into its final position and not deposited continuously in one place and worked along the shuttering to distant points. While being placed in the forms the concrete should be well tamped, rodded or spaded in order to obtain a dense concrete, giving particular care to the concrete around the reinforcements. Light spading of the concrete next to the forms will assist in preventing honeycombing and make surface finishing easier. While tamping is essential, excessive tamping may cause segregation.

The concrete should generally be placed within 30 minutes of mixing, and should not be disturbed after 1½ hours from the time when water was added to the cement. Concrete that has visibly commenced to set before it is placed should not be used. "Retempering" — breaking up the concrete and mixing with added water — should not be permitted as the addition of this water seriously impairs the strength, and the operation of placing will disturb the setting action.

Various types of vibrators are now available for consolidating concrete, and when properly used, they permit the use of dryer mixes. This makes it possible to produce higher strength by the reduction in the amount of water required for placing. Excessive vibration is harmful as it causes segregation,

and it must be stopped when the water rises to the surface of the concrete.

CURING

Generally, insufficient attention is given to properly curing the concrete after pouring, but the importance of keeping the concrete moist while hardening cannot be too strongly emphasised. Tests show that moist curing during the early stages greatly increases the strength and assists in securing a hard, dense surface resistant to abrasion.

Adequate curing is a vital factor in the production of watertight concrete. Surface cracks are sometimes caused by too rapid drying out causing the surface to shrink more quickly than the interior of the concrete. All exposed surfaces should be protected from drying out for at least seven days, but with high alumina cement, the concrete need only be kept thoroughly wet for 24 hours.

A common method is periodically to apply water through a hose to the exposed surfaces, but better results are obtained by improved methods which maintain the moist conditions more constant. Ponding is a good method of curing for horizontal surfaces: an inch or so of water is flooded over the area and retained in position by small earth banks. Alternatively, the surface can be covered with a layer of wet sand, or covered with hessian, canvas, or similar material which can be kept saturated for the required period.

CONSTRUCTION JOINTS

Construction joints are often unavoidable in reinforced concrete. When properly made, they may be as strong as the concrete elsewhere, but a badly-formed joint is a source of weakness, since lack of adhesion may cause the joint to open sufficiently under tensile stresses due to shrinkage to allow access of water. This leads to corrosion of the reinforcement and gradual disintegration of the concrete at the joint.

Before new concrete is joined to old, all laitance must be removed from the face of the existing concrete by hacking or scrubbing with a wire brush, preferably not later than 24 hours after the concrete is poured. The surface should then be cleaned down and thoroughly wetted by hosing, and given a thin coat of neat cement grout, followed by a ½ in. layer of 1 : 2 cement-sand mortar, followed at once by the new concrete.

Care must be taken to work and ram the mortar and fresh concrete against the existing surface and thoroughly incorporate

the layer of mortar with the new concrete. Where the old concrete is immature, the coating of grout may be sufficient. Precautions are necessary when the new concrete is made with a different type of cement, and expert advice should be obtained.

The number of construction joints should be reduced to a minimum to suit each day's work, and their position given careful consideration. Generally, they should be made at positions of minimum shear, i.e. at mid-span for beams and slabs, and not over or near the supports.

A stop-board should always be used, and for beams and slabs, the face of the joint should be vertical. It is advisable to use a keyed joint, particularly for water-retaining structures, and this rebate can be easily formed by nailing a batten to the stop-board.

Columns should be poured to within about 2 in. of the beam soffits at least 2 hours before the beams and slab are poured to enable the concrete to settle. Projecting beams at the top of concrete walls should likewise be poured a few hours after the wall panels.

WATERTIGHTNESS

Watertight concrete can be obtained provided correct methods of construction are employed with careful attention to various essential requirements. It is a prime necessity that the thickness of concrete and the amount of reinforcement be designed in accordance with good practice, with the effective tensile stress in the concrete limited to prevent cracking. Although cracks may be of no structural significance, they are objectionable in any structure from the viewpoint of appearance. In water-retaining structures, however, it is essential to prevent them developing to ensure watertightness.

Assuming the design has been properly executed, the main causes of cracking are poor quality concrete, faulty construction joints, and shrinkage. As impermeability is required, it is imperative to produce a dense concrete. Increasing the cement content increases impermeability, but excessive cement increases shrinkage, and therefore a compromise is desirable. A concrete mix 1 : $1\frac{2}{3}$: $3\frac{1}{3}$ is recommended.

The aggregates must be of low porosity, clean and well graded with adequate fines in the sand, and the concrete thoroughly mixed and placed into position, with extra care given to any necessary construction joints. Excessively wet or very dry mixes will prove unsatisfactory, the former having high shrinkage while the latter will tend to be honeycombed. For

thin sections, the quantity of mixing water should not exceed about 5½ gallons per bag of cement. This amount includes the free moisture in the aggregates, for which the proper correction must be made as described previously on page 91. Effective moist curing is particularly important as tests indicate it reduces permeability. The concrete should be kept moist for a period of at least two weeks.

Summarised, the following rules should be observed:

1. Use only clean, well graded aggregates of low porosity —foreign matter may develop into leakage channels.
2. Adequate fines in the sand are essential.
3. Use plastic, workable mixtures without excessive water —normally about 5 gallons per bag of cement will suffice.
4. Thoroughly mix the concrete for two minutes to give better workability.
5. Give proper attention to placing and compaction, eliminating air pockets but avoiding segregation of the materials.
6. Wherever possible, adopt continuous pouring to avoid construction joints.
7. Where they are unavoidable, be particularly careful in their construction as described under construction joints on page 96.
8. Keep the concrete thoroughly moist for at least two weeks after pouring, and protect the concrete from low temperatures.
9. Do not fill the tank or reservoir until the concrete has attained its proper strength.

Although the use of admixtures may sometimes create improvements under conditions where strict control of the concrete making and placing is impossible, no admixture fully compensates for defective concrete due to poorly graded aggregates, indifferent mixing, or careless placing. For water-retaining structures, where conditions such as unequal settlement, etc., may be expected, it may be advisable to provide a flexible, waterproof membrane to prevent leakage through the cracks which may result from the settlement.

LOAD TESTS ON COMPLETED STRUCTURES

Although loading tests on completed structures are not of great practical value, they may be called for when the workmanship has been bad and there is doubt as to the strength of the structure.

For concrete made with normal Portland cement, the test load should not be applied before six weeks after concreting, and it is usual to specify that the test load should be one and a half times the designed superimposed load plus one half the dead load.

Prior to the test, it is prudent to erect under the floor to be tested supports strong enough to carry the whole load, leaving a space of about one foot or so underneath the floor members for the insertion of the deflectometers. The deflection is measured by the deflectometers as the loading is added and later while the load is being removed.

The load should be left in position for a period of twenty-four hours before removal.

The structure may be considered to have passed the test if the maximum deflection at the end of the twenty-four hours period does not exceed the value of "D" as given by the following :—

$$D = \frac{.001\ L^2}{12\ t}$$

Where L = the span
t = the total depth of the slab or beam.
D = the maximum deflection — all expressed in the same units.

If the deflection exceeds the value of "D" as given in the above formula, the construction may be considered acceptable if within 24 hours after the removal of the load, the slab or beam shows a recovery of at least 75 per cent. of the observed deflection.

If the structure fails to pass the test, it is usual to require the defective section to be either removed or strengthened, or where practicable, the load rating of the structure reducd in the same ratio as the test load is to the required design strength.

The loaded area for a slab test should extend over the whole span, its breadth at right angles being about twice the span. For a secondary beam, the whole panel should be loaded on either side of the beam for the full span of the beam, and for

a main beam, the full bay on each side of the beam must be loaded. The load may be applied with bricks, cement in bags, sand, pig iron or similar materials placed on top of the floor, while water in tanks placed on top of the floor may be suitable for beam tests. Care must be taken to see that the test member is not relieved of any load through arching action in the stacked material.

FROST

Frost has a detrimental effect on green concrete. If the concrete freezes before the initial set takes place, the effect is limited to the postponement of the setting of the concrete with slight loss of strength. If, however, the initial set has commenced, then the damage is more serious. The freezing of the concrete causes expansion of the moisture, breaking down the adhesion of the various particles of stone, and when this occurs the ultimate loss of strength is sufficient in many cases to necessitate the demolition and reconstruction of the work.

As in most parts of Australia, long periods of frost are infrequent, it is not customary to make use of methods such as are used in colder countries for continuing the work of concreting until the frost goes. If, however, concrete has been laid immediately prior to frost, the greatest care must be taken to protect the green concrete and to allow it ample time to set and harden before the forms are removed. This is particularly important as, even if the concrete is not frozen, the extreme cold retards the setting. Concrete work can best be protected with bags and in more severe weather with clean straw, but if the work to be protected is in a large building, a better method may be to keep the temperature above freezing by the use of stoves and braziers.

Even when precautions are taken a certain amount of damage may be done to the top surface of the concrete, but as a rule this does not go deeper than $\frac{3}{8}$ in. and can be made good.

The heat generated during the chemical change which occurs during the setting of the concrete is sufficient to prevent the concrete being frozen if it is well covered up. The thickness of boards on sides where formwork is used is normally sufficient to prevent damage by frost.

When it is essential for concreting to continue with the temperature near freezing point, it is essential that the temperature of the placed concrete be not below 40°. Heating

the mixing water, and passing a steam jet through the aggregate, will make this possible, and sometimes Portland cement containing calcium chloride is used.

The formwork must be left in position longer during frosty weather and the concrete must be carefully examined before striking.

Although precautions may have been taken during the actual mixing, proper attention must still be paid to the covering of the work to protect it from further frosts.

ALTERATIONS AND EXTENSIONS TO EXISTING WORK

The problems of bonding new reinforced concrete work to existing work can be simplified if, as is often the case, it is possible to foresee at the time of constructing the original work that modifications or extensions will be required in the future. Since a certain number of construction joints are desirable in work of important size, it is often found convenient to leave a clean joint between the old and the new work, so that no bonding is actually required. In the case of a frame building, the foundation at the end where an extension is to take place will be made large enough to support duplicate columns which will be the support to the future structure. Vertical splice bars are left projecting, coated with cement grout, and temporarily covered with a "lean" concrete. When the extension is built it will have independent columns and beams requiring no bearings on the original work, although they may butt up close to the existing work.

Sometimes, for architectural or other reasons, this method is not practicable, and the following provision must be made:

(a) The external columns, main beams and other members at the end which will form the junction of the structure should be designed to take the full loading which will come on them when the future extensions are completed.

(b) Pockets must be formed in main beams and columns as necessary, to accommodate the ends of future beams. These may be temporarily formed by blocks of cinder concrete which can be readily cut away when required, or by timber casing.

(c) Reinforcing steel, suitably protected, should be left projecting for bonding to the future beams. Occasionally

protection is given by painting with cement grout, but this is unsatisfactory and unsightly as the cement grout will not adhere to the steel for any length of time. A better method is to paint the exposed bars with two or three coats of oil paint, taking care to brush it into the junction where the rods leave the concrete. When the new extension is added at a later date this paint must be burnt off to leave a surface to which the new concrete will adhere.

(d) Recently, solutions have been introduced which, if painted on the formwork, have the effect of retarding the set of the cement on the surface of the work, and they can be obtained to penetrate to different depths. When the formwork has been removed, the concrete surface is immediately scrubbed with a wire brush and the aggregate is exposed. This treatment, applied to the surface of the concrete where the future junction will be made, will improve the bond and consequently the connection.

A certain amount of cutting away is usually required in preparation for bonding new to old concrete work. It is often necessary to cut back sufficiently to splice reinforcement on to existing steel, or sometimes it may be necessary to drill holes to receive bonding rods. The least that would have to be done is to remove the outer skin of the old work to expose clean concrete surfaces. It is rarely possible to get a good bond with concrete surfaces exposed near industrial centres.

Extra care must be taken in fixing the new formwork to make it fit snugly to the old work to prevent the formation of ridges caused by escaping cement grout. Immediately before concreting begins the surface should be swilled with water and coated with neat cement paste followed by a 1 : 2 cement-sand mortar, followed at once by the new concrete, which is rammed against the face of the old concrete. If this method is followed the loss in strength at the joint is not serious. When compressive stresses only exist between the old and the new work, the surfaces should be trimmed off at right-angles to the direction of the compressive force. When tension and shear act between the surfaces, it is necessary, in addition, to provide bonding reinforcement, either cast in the original work, or set in holes drilled for the purpose.

Special precautions should be taken when bonding Portland cement concrete (both ordinary and rapid hardening) to aluminous cement concrete, as given for construction joints, page 96.

CONCRETE FINISHES

The architectural effect of a reinforced concrete structure must depend primarily on the proportions and the arrangements of the masses of the building. Purposeless decoration should be avoided, but much can be done to improve the appearance of concrete as it comes from the forms.

The normal finish of a reinforced concrete structure is produced by making good any slight honeycombing and day's-work joints with cement mortar, removing the most prominent board marks and rubbing down the surface with a carborundum block and water. A cement and sand mortar, coloured if desired, is then well rubbed into the surface with a wooden float, giving a pleasing stone-like appearance.

If a very good surface is required it is essential for special attention to be given to the formwork, which must be true to line, the boards thicknessed and undistorted, and the concrete must be tamped against the forms to avoid honeycombing. In the rubbing down process all traces of the board marks should be removed, and it is an advantage to use a power-driven carborundum stone.

The "stoning-up" process is still more effective if a retarding liquid is used on the formwork. There are several of these liquids on the market, which are brushed on to the formwork a short time before concreting. They have the effect of retarding the set of the concrete immediately in contact with the formwork, and when the latter is struck the concrete surface is wire brushed immediately, leaving a rough, pebbly surface to which the finish will readily adhere. White or coloured cement mixed with suitable white or coloured sand may be used in this treatment. If suitable aggregate is available, the concrete surface may be left after the aggregate has been exposed by wire brushing. The success of this method depends on the evenness with which the retarding liquid is distributed, so that the effect will not be patchy, and care must also be taken to ensure that every batch of concrete is of the same mixture. The exposed aggregate finish is sometimes obtained by treating the surface of the concrete with dilute hydrochloric acid, which has the effect of destroying the cement near the surface and permitting its removal by scrubbing. All traces of the acid must be washed away before leaving the work.

Sometimes for the sake of cheapness, no rubbing down or treatment of the surface is done beyond filling up honeycombing and removing prominent fins, the whole surface being washed down with a thick coat of cement grout. This is not satisfactory,

excepting as a temporary expedient, since the grout usually begins to peel after a few months.

A pleasing texture to a concrete surface may be obtained by bush-hammering, which also removes the surface skin, exposing the aggregate. The process being somewhat costly, it should be used only for limited areas, and the reinforcement must be given sufficient cover to allow for it.

To produce a coloured concrete, coloured cement is used, or colouring materials are mixed with the cement at the site. As this requires special sands and aggregates and the resulting concrete is expensive, it is usual to apply a thickness of about 2 in. on the surface; the surface concrete being cast at the same time as the structural concrete, separated temporarily by an inner movable form, which is raised in lifts as concreting proceeds. Care must be taken to keep the structural concrete and the facing concrete at the same height as the work proceeds, and if the cement aggregate ratio is approximately the same, a perfect union of the two concretes will result, with no danger of separation.

Special concrete paints are sometimes used to give a coloured finish. These should be used in accordance with the manufacturers' instructions, as they mostly rely on chemical reaction, and in most cases a suitable primer is previously applied to neutralize the free lime in the concrete.

A variation of the flat concrete surface may be obtained by panelling the work, and when a perfectly smooth surface is required the formwork may be lined with special wall boarding which is free from grain and timber defects.

Corrugated iron can be used to produce a corrugated surface, but a more satisfactory method is by nailing 1 in. by 1 in. fillet strips on to the formwork. This gives a pleasing surface and is suitable for decorative panels or in bands around the building.

Precast concrete slabs are often used for facing reinforced concrete buildings. These slabs can be produced with a great variety of exposed aggregates and other finishes. They save the use of formwork on the outside of the wall and for this purpose are built up ahead of the concreting.

The possibilities of producing pleasing finishes to concrete have not yet been fully explored, but sufficient has been done to demonstrate that reinforced concrete is no longer open to the reproach that it produces dull-looking structures.

PLASTERING ON TO CONCRETE

It is often unsatisfactory to attempt to plaster directly on to concrete as left from the forms. Sometimes the concrete surfaces are hacked, thoroughly wetted and plastered, but this is laborious. An alternative method is to paint the forms with a special retarding liquid, enabling the aggregate to be exposed by wire brushing when the formwork is struck. Another method which is useful in the case of plastering ceilings on the underside of concrete floors is to spread a ½-in. layer of stone chippings over the formwork. The concrete spreads between and partially around the chippings, and, unless the concrete has been mixed too wet, it will be found that when the formwork is struck there is a sufficiently rough surface exposed to afford an excellent key for the plaster.

The formwork must be set ½ in. low to allow for the chippings.

In all cases the surface of the concrete must be wetted so that it will not rob the plaster of moisture and prevent it from setting. On the other hand no surplus water must be left on the surface.

FLOOR FINISHES

Usually some kind of a wearing surface finish is applied to concrete floors. In the case of factory floors the finish is often omitted, and it is necessary to ensure that the concrete will have good-wearing properties and will not dust excessively. Many concrete floors doing heavy duty over long periods have been almost dustless, indicating that there is no real difficulty in producing a practically dustless floor.

The causes of dusting are:—

Excess water in mixing.
Sand too fine and uniform.
Soft dusty aggregate.
Excessive trowelling of the surface.
Too rapid drying out of the surface.

It is important that all the materials used in the concrete making should be clean and that they should be strictly in accordance with the standard specification. In choosing the coarse aggregate, material which has a high resistance to abrasion should be used. For example, limestone, which is dusty in itself, would not be suitable. It is most important that the quantity of water should be reduced to the minimum consistent with enabling adequate tamping and screeding of the concrete to be carried out.

When pools of water form on the surface of newly-placed concrete, a scum consisting mainly of fine sand and lime comes to the surface. When this dries out it has no strength and dust is easily raised up from it, even by ordinary foot traffic. It is essential to keep the concrete moist for several days after laying so as to enable a natural set to take place instead of a drying out. This is usually done by covering with wet sand and sometimes by ponding. If these precautions are taken, a satisfactory, almost dust-less floor should be produced.

If, however, the use of the building — such as for precision instrument work — calls for absolutely no dusting, there are proprietary preparations on the market which can be applied and there are one or two which can be recommended. The application of a solution of silicate of soda is useful, but it cannot be regarded as permanent. The solution, consisting of one part of silicate of soda to four parts of water, is applied in a number of washes until the surface will not absorb any more.

When a floor is likely to be subjected to wheel traffic it is usual to apply a fine granite concrete finish. If this is placed after the main concrete has set, it ought to be not less than $1\frac{1}{2}$ in. thick, but if it is laid within one hour of laying the base concrete, it may be reduced to the minimum of $\frac{1}{2}$ in. thick. Granolithic is made from one part of Portland cement to three parts of granite chippings from $\frac{3}{8}$ in. downwards, the fine dust being excluded.

Sometimes a timber floor finish is required, and these can be supported on dovetailed wood strips running in the same direction as the main reinforcement and embedded about $\frac{1}{2}$ in. in the top of the slab, or special clips can be concreted in the slab to hold the runners to which the boarding is nailed down.

There are various proprietary finishes which can be applied in accordance with the manufacturers' directions, or laid by the manufacturers themselves.

Roofs are often covered with malthoid or similar material, although sometimes they are finished with asphalt applied in two $\frac{3}{8}$ in. coats. It is an advantage to cover the asphalt with some white material such as asbestos-cement tiles to reflect the rays of the sun and reduce transmission of heat to the concrete. It is desirable to lay insulating material such as vermiculite concrete before asphalting.

This reduces the heat flow through the roof and prevents excessive expansion and contraction of the structure.

SPECIFICATION

for the execution of

REINFORCED CONCRETE

to be carried out to the designs of

THE A.R.C. ENGINEERING CO. PTY. LTD.

(hereinafter referred to as the A.R.C. Co.)

EXTENT OF WORK

The work consists of Reinforced Concrete Construction as shown on the A.R.C. Co. Drawings No..... to be read in conjunction with the plans, specifications and other particulars provided by the Architects for the work.

SUPERVISION

The Contractor must maintain a competent foreman on the job to supervise, and to receive instructions.

MATERIALS

Cement. The cement shall be Portland Cement complying at the time of use with the current Standard specification and tests for Portland Cement issued by the Standards Association of Australia.

It shall be delivered in the sound original packages of the manufacturers, plainly branded, and must be stored in a watertight shed on a floor raised at least 6 in. from the ground. The unit of measurement shall be one paper bag weighing 94 lbs., equal to one cubic foot.

Fine Aggregate. Shall consist of hard, silicious, sand or other approved inert material with similar characteristics, having clean, hard, uncoated grains, free from lumps, soft or flaky particles, silt, loam, clay, organic matter or other deleterious substances.

The grains shall be uniformly varying in size, and must pass through a screen with a mesh of 3/16 in. square measured in the clear, and not more than 10 per cent. shall pass through a British Standard sieve No. 100.

Coarse Aggregate. Shall consist of crushed stone, gravel, or other approved inert material with similar characteristics, having

clean, hard, uncoated particles, free from soft, friable, porous, elongated or laminated pieces, dust, loam, organic matter, or other deleterious substances.

The particles shall be uniformly varying in size, and must pass through a screen with a mesh $\frac{3}{4}$ in. square measured in the clear and be retained on a screen with a mesh of 3/16 in. square measured in the clear.

The maximum size of the aggregate shall not be larger than one-quarter of the narrowest dimension between forms of the member for which the concrete is to be used, nor larger than threequarters of the minimum clear spacing between bars.

Water. The water shall be clean and free from harmful matter.

MATERIALS

Reinforcements. The whole of the reinforcements shall be supplied by the A.R.C. Co.

It will consist of Mild Steel Bars and Fitments cut to length and bent to shape, and A.R.C. Fabric in sheets or rolls.

The Contractor to allow for placing and fixing the Mild Steel Bars, and laying the A.R.C. Fabric accurately in accordance with the detail drawings supplied by the A.R.C. Co., and maintaining them in their correct position during the pouring of concrete.

COMPOSITION OF CONCRETE

The concrete shall be composed of Portland Cement, fine and coarse aggregates in the proportions specified, and water to give the required consistency.

Proportions. The proportions by volume of the concrete in the various parts of the work will be specified on the drawings, and shall be accurately measured as follows:—

Grade of Concrete	Cement	Fine aggregate cubic feet	Coarse aggregate cubic feet
C	94 lbs.	2	4
B	do.	$1\frac{1}{2}$	3
A	do.	1	2

The quantity of water used shall be the minimum consistent with practical workability, and shall be varied as required to suit the moisture content of the aggregate, and to produce concrete having the specified slump.

STRENGTH

Concrete mixed in the proportions stated above shall have compressive strengths at 28 days after placing not less than the following:—

Grade	Concrete Mix	Strength
C	1 : 2 : 4	2200 lbs. per sq. in.
B	1 : 1½ : 3	2600 lbs. per sq. in.
A	1 : 1 : 2	3000 lbs. per sq. in.

TESTS

The Contractor shall make standard test cylinders 6 in. diam. when required of the concrete being used in the work, and after maturing, they shall be tested as directed by the A.R.C. Co. The cost of all testing of materials and if necessary of the finished structure shall be borne by the Contractor.

MANIPULATION AND WORKMANSHIP

Mixing. An approved mechanical batch mixer shall be used. Mixing shall continue for at least one minute after all materials are in the mixer. When mixing ceases, the mixer and all handling plant shall be thoroughly washed out.

Consistency. The consistency of the concrete shall be determined by means of the S.A.A. slump test; the slump for concrete in various members shall be as directed by the A.R.C. Co., but normally should not exceed the following amounts:—

Footings	3 in. slump
Columns	4 in. slump
Walls	5 in. slump
Floor Slabs	4 in. slump
Beams	5 in. slump
Impermeable work . .	4½ in. slump

Placing Concrete. Concrete shall be placed in the final position in the forms within a period of 30 minutes from the time of mixing. Retempered concrete shall not be used.

The concrete shall be thoroughly rammed into position around the reinforcement, and properly spaded against the forms to ensure a good surface free from honeycomb. When concreting is once started, it shall be carried on as continuously as practicable until the section is completed.

Temporary openings shall be provided at the base of column and wall forms and at other points where necessary to facilitate cleaning and inspection immediately prior to depositing concrete.

The ribs and slabs of "T" and "L" beams shall be concreted in one continuous operation.

Walls shall be concreted in horizontal layers about 12 in. depth. Granolithic finish to slabs shall be laid immediately after the slab concrete is placed.

Construction Joints. Day's-work joints shall be made in the following positions unless shown to the contrary.

1. Slab and beams, at the middle of the span.
2. Columns, 1 in. below the junction of column and beam, haunch, or capital.
3. Walls, vertical joints in sections staggered about 2 ft. over each other.

Joints shall be made at right angles to the main reinforcement.

Immediately before recommencing, the surface shall be thoroughly cleaned with water and coated with a layer of 1 : 2 cement mortar. (Joints of long standing shall be hacked back to a clean surface and the dust removed with a wire brush before carrying out this procedure.)

Frosty Weather. No concrete shall be deposited when the temperature is below 36°F on a falling thermometer, or below 34°F on a rising thermometer, unless specially approved precautions have been taken to ensure protection of the concrete during setting. In frosty weather, newly-placed concrete must be kept properly protected.

Curing. After placing, concrete shall not be jarred, walked on or otherwise disturbed during setting.

In hot weather and during high winds, freshly placed concrete must be kept watered and protected by wet sand or other approved method for at least 5 days after placing.

Defective Work. Any concrete damaged during setting from any cause whatsoever or other defective concrete shall be cut out and replaced by the Contractor at his own expense.

Placing Reinforcement. The reinforcements shall be fabricated, and placed exactly as shown on the detailed drawings, and supported so as to give the correct cover, which must be maintained during concreting.

Formwork. Formwork may be constructed of any suitable materials. It must be true to line and level, strong and well braced to carry the wet concrete without deflection or deformation, and with close joints to prevent loss of cement.

The bottom of beam forms of over 20 ft. span shall be given a small camber.

For face work, the boards must be dressed and thicknessed, and have shot edges.

The design of the formwork must be such that it can be struck in the following order: Columns, beam sides, slabs and beam bottoms. To facilitate striking, bolted and wedged connections should be used in preference to nails.

Cleaning. Immediately before concrete is placed, all forms shall be thoroughly cleaned out and swilled with clean water. Forms must be thoroughly cleaned before re-use.

Inclined Work. The upper surfaces of all concrete at a slope of more than 30° shall be shuttered.

Striking. The formwork shall be eased off gradually in order to allow the structure to take up its load gradually. The time interval between placing of concrete and striking depends on the weather, and the responsibility for removal of forms must rest with the Contractor.

After formwork is removed, concrete surfaces shall be cleaned down to a fair face, unsightly projections removed, and all holes filled with cement mortar.

Cutting Holes. No tampering with the concrete whether by cutting holes or otherwise will be allowed without the approval of the A.R.C. Co.

Completion of Work. On completion of the work, all surplus material and rubbish shall be removed from the site, and the work handed over in a clean condition.

FORM WORK

Careful attention should be given to the design of forms, as the cost of formwork is one of the major items in the cost of reinforced concrete construction. The designing engineer can considerably assist by reducing variations of sections to a minimum, and by providing simple profiles that, even at the expense of more concrete, may lead to economy.

The formwork must be strong enough to retain and support the wet concrete until it has set and hardened sufficiently to be self supporting. It is essential that the forms be properly supported and braced or tied together so as to maintain the desired position and shape during and after placing the concrete. Beam soffit forms should be given a camber of about $\frac{1}{4}$ inch per 10 ft. of span to allow for the formwork settling down when filled with concrete, and still leave a slight camber when the work is completed. The forms must be accurately erected, true to line and level, with a proper allowance made for deflection under load. They must be sufficiently tight to prevent leakage of mortar through the joints, otherwise the appearance of the work will suffer, due to the loss of cement from the concrete and to the unsightly fins which will form at each open joint. The surface of the formwork must be clean and smooth if a good finish is required on the concrete work, although for unexposed and rough work, undressed timber may be used. It is more economical to use shuttering that will give a smooth finish than to remove fins, fill holes, and repair other defects after the shuttering has been removed. All rubbish, such as chips, shavings and sawdust, must be removed from the interior of the forms before pouring concrete, and in the case of column and wall forms, temporary openings should be provided at the bottom to facilitate cleaning and inspection.

MATERIALS

Formwork is usually constructed of timbers such as yellow pine, fir, and hardwood, or of steel.

Timber is convenient as it is easily put together and can be taken down, altered, repaired and reassembled without difficulty. Its life, however, is limited, and on some types of work where repetition is possible, it may be more economical for formwork to be protected by sheet iron or wholly made of steel.

For general conditions in this country, Baltic pine is the timber commonly employed for the shuttering. It should be well seasoned and free from loose knots, particularly if it is

to be exposed to the weather for any length of time after it is made up. Hardwood is used to a large extent for the joists, bearers, props, and braces, etc., but due to its decreased weight, oregon is often employed where the spans are longer.

Where special calculations are not prepared, the following nominal sizes are common for average types of beam and slab construction :—

Boards for slabs, beam sides soffits and columns	1 in.
Joists supporting slabs	4 in. x 2 in. at 2 ft. centres.
Bearers supporting joists . .	4 in. x 3 in. at 4 ft. centres.
Props to beams and slabs . .	4 in. x 3 in. at 4 ft. centres — properly braced.

The use of steel forms is increasing, and although the first cost is higher than that of timber for a given work, ultimate economy may result owing to their greater durability, if a large number of uses can be obtained.

Steel forms may be constructed by the Contractor, but various proprietary makes are available. The standard sizes of these plates are 2 ft. by 2 ft., but fractional sizes are obtainable.

They are supplied concrete-faced for a plaster finish, or clean-faced for a smooth finish.

Steel scaffolding and joists are often used, and offer advantages, as the members are adjustable so that they can be used on a wide range of jobs, and, unlike timber members, are not subject to warping, etc., due to the weather, and have a longer life.

TREATMENT

The inside of forms should be coated with mould oil before concreting begins, to prevent the concrete adhering to the forms, and also to prevent deterioration of the timber by the action of the cement. A good mould oil should not stain the concrete, injure it by chemical action, or be absorbed by timber, and it must be insoluble in water. After the forms have been removed, they should be cleaned and oiled before re-using. It is important that the mould oil does not come in contact with the reinforcing, as otherwise the bond will be destroyed. The reinforcement should be placed after the mould oil has been applied. If the forms are not oiled, they should be thoroughly wetted before placing the concrete, in order that the wood shall not absorb moisture from the concrete.

REMOVAL OF FORMS

Many specifications place the responsibility of the time of removal of forms on the contractor. Care must be taken against premature removal, at the same time economising in form work by releasing the shutters as soon as the concrete has sufficient strength to be self-supporting or requires a minimum of external support. The removal is facilitated if the formwork has been properly constructed so that it can be removed in the proper sequence.

It should be possible to remove the beam sides first, followed by the formwork supporting the slab.

The supports to the beam soffits remain in position for a longer period, and it ought not to be necessary to disturb them to strike the other formwork. The column forms have in many cases been struck before the floor formwork is finished.

The props should stand on folding wedges to facilitate striking without jarring the new work, and also to enable the final levelling to be carried out more accurately.

The supports should be eased gradually, in order to prevent the load being suddenly transferred to the concrete. For this reason, wedged and bolted connections are preferable to nailed joints. The only tool that should be necessary, in addition to perhaps a spanner, is a small crowbar or nailbar, which is useful either for withdrawing nails (the heads having been left proud) or for prising off boards. The use of a heavy hammer should be prohibited.

It is difficult to state definite times for striking the formwork because this depends on the type of cement, the quality of the concrete, the weather, length of spans, the ratio of the dead load to the total design load, and the type of construction. During cold and frosty weather, the concrete will harden slowly and the period of frost — at least — should be added to the time allowed. Before removing soffit forms, the concrete should be tested by striking with a hammer; if it has hardened sufficiently, it will "ring" when the concrete is struck.

If members are likely to be subjected, during subsequent constructional operations, to loads exceeding the design load, provision must be made to carry the extra load, either by leaving the forms in place or by providing props supported on members which are strong enough to carry the total load. This shoring must be left in position until the risk of abnormal loading is removed.

The following table gives approximate safe times for removal of formwork when standard Portland cement is used, and assuming normal temperatures about 50°F, and that the work will not be loaded for several days after the given period. When rapid hardening cement is used, the times may be reduced.

Part of Structure	Minimum Period Before Removal
Beams sides, vertical walls, and columns	3 days
Slabs up to 10 ft. span (props left under and not disturbed)	5 days
Removal of props to slabs	10 days
Beam soffits up to 20 ft. span (props left under)	8 days
Removal of props to beams	21 days

Under favourable conditions, shutters to beam sides, columns, and walls can be removed after 24 hours. For important work, the result of strength tests may be used as a guide to the time required before striking.

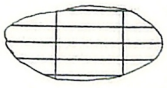
It is important to commence proper curing of the concrete as soon as possible after the initial set has taken place, and to keep the exposed surfaces moist for at least five days.

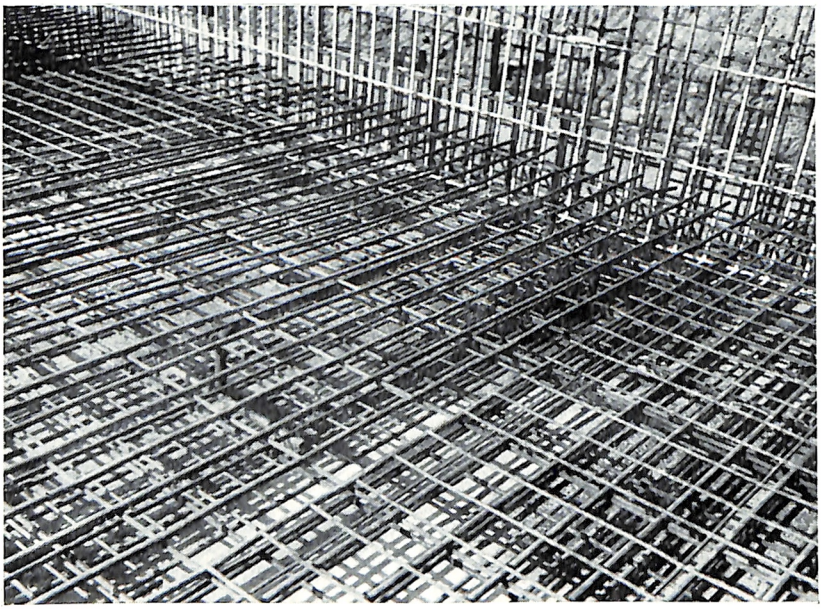
LAYING A.R.C. FABRIC

A.R.C. Fabric is supplied in either standard rolls and sheets, or in sheets cut to the length required on the drawings.

The following points will be of assistance when using A.R.C. Fabric:—

1. When commencing to unroll fabric, secure the free end of the roll by dog spikes or weighting.
2. When the unrolling has been carried out sufficiently far for cutting, place a plank tightly against the unrolled portion to stop it re-rolling.
3. Cutting is easily done by using bolt-cutters.
4. For rectangular meshes, make sure that the fabric is laid with the main wires in the correct direction, normally in the direction of the shorter span. On some occasions, they are placed in the direction of the longer span; therefore, the drawings should be closely followed, the direction being shown thus:—





5. It is usually sufficient to place adjoining sheets with their respective outside main wires together, i.e. the side lap would be 3 in. for rectangular meshes and 6 in. for square meshes. Where a square mesh is used to reinforce a suspended two-way slab, a side lap of 9 in. to 15 in. is required, but this will be shown on the drawing.
6. It is important that the fabric be given the correct cover as shown on the plan. Any increase in the cover decreases the effective depth of the slab and reduces its strength; insufficient cover will not protect it against rusting.
7. It is advisable to support the bottom fabric in suspended slabs on small precast concrete blocks.
8. Where fabric is to be placed in the top of a slab for cantilever reinforcement, or to provide against negative moments, it is essential to use suitable hurdles or chairs under the fabric to maintain it in its correct position near the top of the slab.

MILD STEEL BAR REINFORCEMENT

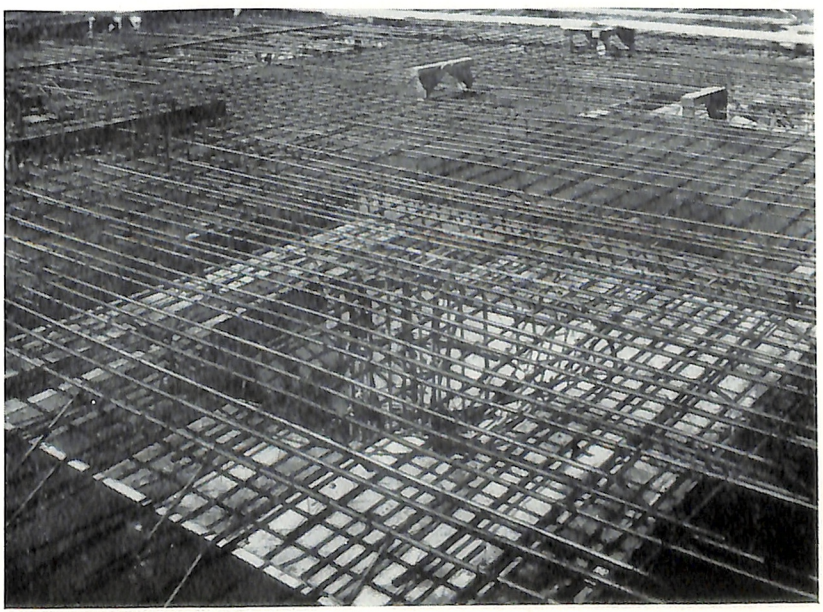
Standard practice for dimensions of bars is outside to outside (overall) measurements. For stirrups, ligatures, and spirals, inside dimensions are given.

All shavings and debris should be removed from the formwork before placing reinforcement. A little rust on the bars is not detrimental, as it improves the bond of the steel with the concrete, but heavy rust and scale should be removed with a wire brush.

The splice bars to foundations should be fixed by a template so that the column reinforcement, which is assembled after the footings have been concreted, will fit accurately in position. After the columns have been poured up to within one inch of the beam soffit, the slab and beam formwork is completed, the beam reinforcement placed, and finally the slab reinforcement laid. Using A.R.C. Fabric, this is done expeditiously.

The reinforcement must be wired together sufficiently to prevent displacement during concreting. For this purpose, annealed wire about 18 gauge, cut to approximately 12 in. lengths, is required, the quantity required averaging about 14 lb. per ton of steel bars. After fixing, the loose ends should be turned into the concrete and not left projecting out towards the forms.

As tie wire is not an item of reinforcement, but one of the accessories of reinforcement assembly used by the contractor, it is usually not included in our quotation for the reinforcement.



Beam reinforcement should be supported on small precast concrete blocks to give the correct cover, unless supported by our standard type T beam stirrup.

For ground floor slabs, the fabric may be supported on pipes which are moved along as concreting proceeds. Fixing of reinforcement should be carried out by men trained in this type of work, otherwise continuous supervision by a competent person is required.

REINFORCED CONCRETE ROADS

Reinforced concrete has been extensively used in the construction of roadways for many years, either as a foundation under wood blocks, asphalt, or other surface, or in accordance with the more modern practice as a complete concrete road. Many of these earlier roads and foundations were reinforced with A.R.C. Fabric, and have given excellent service under increasingly heavy traffic conditions which were never contemplated at the time of construction.

Reinforced concrete roads have the advantages of freedom from dust in summer and from mud in winter, absence of skidding, low tractive effort, good riding qualities and visibility, ease of scavenging, and low maintenance charge combined with reasonable first cost.

Important factors influencing the design of concrete roads are the present and anticipated volume, weight, and type of traffic, the quality and strength of the concrete to be used, the nature and bearing capacity of the sub-grade, and because of its influence on this last factor, the climatic conditions for the particular location.

DESIGN OF CONCRETE ROADS

The two types of design in general use at present are the thickened edge cross-section and the uniform thickness pavement.

As the stress caused by loads at the edges of a concrete pavement is greater than the stress caused by the same load on the centre section, the first type is designed to give equal stresses under the design load. In the uniform thickness pavement, the constant thickness of cross-section is that required to resist the stresses due to the loads at the edges, and therefore it requires more concrete than the former type. The increase is small for thin slabs of about 6 in. and less thickness, but becomes appreciable for thicker pavements. However, the overall saving may not be great, and the tendency is towards the use of a uniform thickness. This type has always been widely used in England and the Continent, and its use in these countries is now almost universal.

Although a great amount of research has been carried out to find a sound basis upon which to design reinforced concrete roads, in practice it is difficult to realize the assumptions made.

The following "Sheets" formulae have been widely used in the United States for calculating the slab thickness "t" :—

1. For slabs with "protected" corners, i.e. where dowel bars or other means are used for load transference across the joints,

$$"t" = \sqrt{\frac{1.92\,Wc}{S}}$$

2. For slabs with unprotected corners, i.e. where load transfer across joints is not provided,

$$"t" = \sqrt{\frac{2.4\,Wc}{S}}$$

Where "t" = thickness in inches of slab of uniform thickness.
"W" = maximum static wheel load in lbs.
"S" = allowable working stress for concrete in bending in lbs. per sq. in.
= Modulus of Rupture (usually 600-750 lbs. per sq. in.) / Factor of Safety (usually 2)
"C" = Coefficient of sub-grade support — varies between .8 and 1.8, often assumed as 1.5.

For a thickened edge design, the interior thickness is usually made .85 t, and the edge thickness generally 1.275 t, the latter varying slightly with the shape and width of the edge section used.

The area of reinforcement required is found by the formula :—

3. $$As = \frac{WcL}{2\,fs}$$

Where "L" = length of slab between free joints in feet
"W" = weight of slab in lbs. per sq. ft.
"C" = coefficient of sub-grade support
"fs" = allowable tensile stress in the reinforcement in lbs. per sq. in.

For A.R.C. Fabric, the value of "fs" used is 30,000 lbs. per sq. in.

The area of transverse reinforcement is found similarly by substituting the breadth between free joints in lieu of "L".

There is little doubt that the best way to acquire reliable data is by the construction of experimental roads. A notable example in England is the Oxton By-pass in Nottinghamshire constructed by the Notts C.C., in collaboration with the Road Research Laboratory, for the Ministry of Transport, and opened to traffic early in 1948.

It consists of a number of bays, varying in thickness from 3 in. to 8 in., laid in such a manner that adjacent slabs of equal thickness are reinforced and unreinforced alternately, thus making possible a direct comparison between the two forms of construction.

Some of the slabs are laid on the natural formation of sand and gravel, whilst others have a cement-sand base course. All the reinforced concrete slabs are still in excellent condition, including even those as thin as 3 in., which contain only fine hair cracks (see Fig. 14, Page 122), whilst adjacent unreinforced slabs of the same thickness, and all the 4 in. ones, have disintegrated.

Most of them had to be replaced in 1949 by unreinforced slabs 4 and 5 in. thick laid on compacted sub-grade of various depths of compaction. Rapid failure again took place, necessitating further replacement during 1950 by 4 in. reinforced slabs laid on the original sub-grade.

More than half of the original 5 and 6 in. unreinforced slabs have transverse cracks which are deteriorating and further cracks forming, and even the 7 and 8 in. plain slabs have cracks which are gradually increasing in number.

The major fractures and disintegration which have occurred in plain concrete sections as thick as 6 in. will be seen from Fig. 15, Page 123.

The study of these two photographs makes an interesting comparison, and clearly illustrates the resistance to cracking resulting from the use of suitable reinforcement. The diagram on page 124 shows the effect of reinforcement on cracking in another experimental road.

ERRATA

Page 120

Formula 1 should read-

$$"t" = \sqrt{\frac{1.92\ Wc}{S}}$$

Formula 2 should read-

$$"t" = \sqrt{\frac{2.4\ Wc}{S}}$$

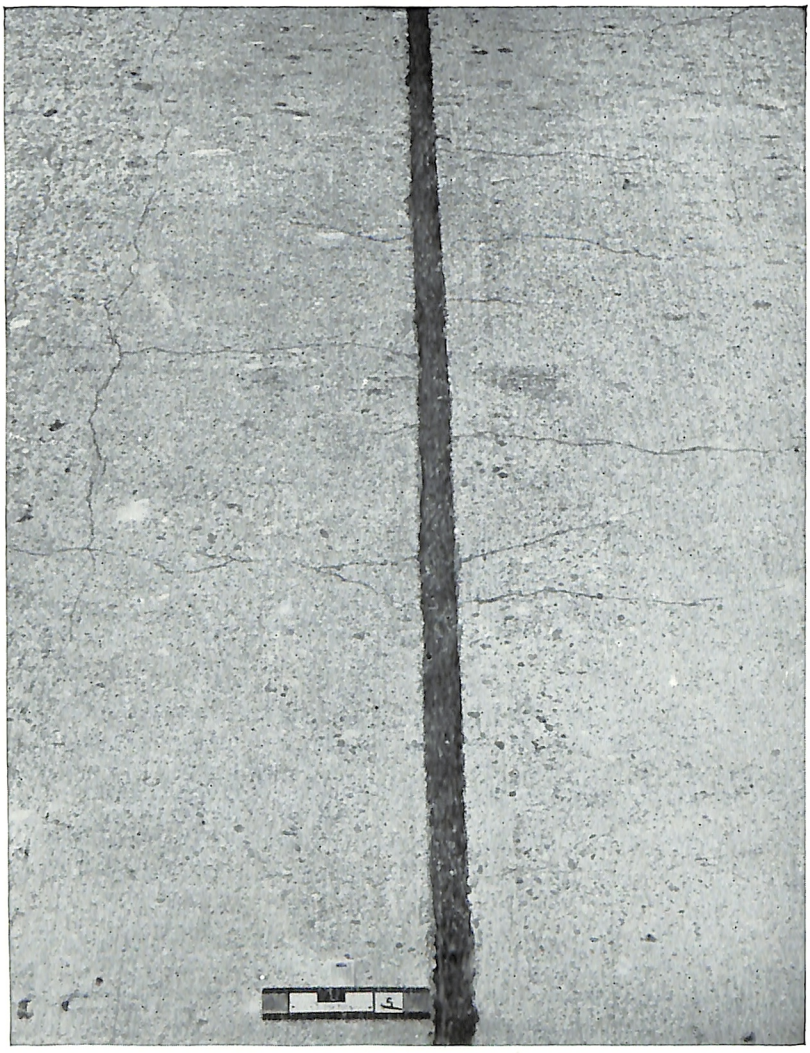


Fig. 14.

OXTON BY-PASS ROAD. Bay No. 22, 3" thickness of reinforced concrete (vibrated) on 2" cement stabilised base.

Original construction open to traffic early in 1948—photograph taken July, 1950.

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Fig. 15.

OXTON BY-PASS ROAD. Bay No. 3, 6" thickness of plain vibrated concrete laid direct on the sub-grade.

Open to traffic at the beginning of 1948—photograph taken July, 1950.

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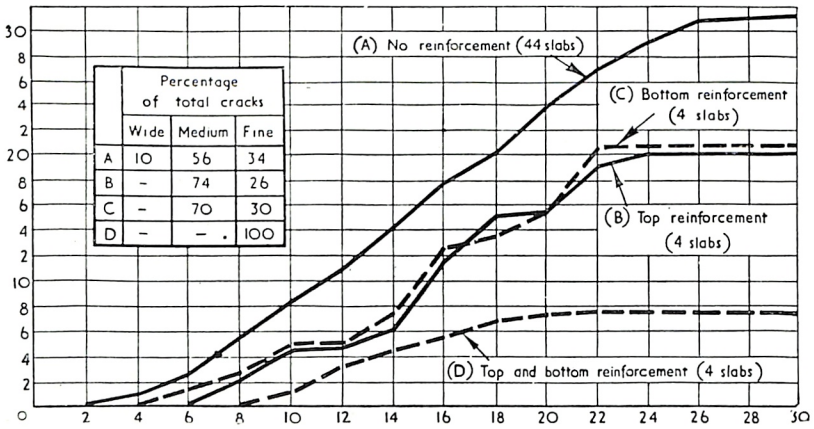
"It will be noticed that both the size and amount of cracking is reduced by increasing the amount of reinforcement." (F. N. Sparkes, M.Sc., M.I.C.E., "The Design and Construction of Concrete Pavements"—Paper presented to the Reinforced Concrete Association, November 14th, 1951.)


(A) No reinforcement (44 slabs)
(C) Bottom reinforcement (4 slabs)
(B) Top reinforcement (4 slabs)
(D) Top and bottom reinforcement (4 slabs)
Percentage of total cracks
Wide Medium Fine
A 10 56 34
B - 74 26
C - 70 30
D - - . 100

The outstanding conclusion from the experiment is that reinforcement greatly increases the resistance to cracking of a concrete road, and even when cracks occur, they do not widen and lead to progressive breaking up of the road as is the case when reinforcement is omitted.

Although the principle of reinforcing concrete roads has been established, there is no general agreement as to the amount of reinforcement or its position in the slab. Top and bottom reinforcement gives the strongest construction, but when one layer is used, it may be placed either in the top or the bottom. As it is important to prevent any cracks on the top surface from opening, there is some advantage in placing the reinforcement in the top.

The reinforcement should have between $1\frac{1}{2}$ and 2 in. cover, and where top reinforcement is used, it is common practice to place and roughly tamp the concrete to within $1\frac{1}{2}$ to 2 in. below the finished surface immediately before placing the top mesh in position, and then pour the remaining concrete without delay.

At expansion joints, additional reinforcement (apart from dowel bars) should be used in the slab, and where the normal slab reinforcement is placed on the bottom, this extra mesh should be placed in the top at the corners.

Our general recommendations for standard types of construction are as follows:—

Concrete 4 in. thick reinforced with No. 9 A.R.C. Fabric for light traffic such as housing estates where the formation is good.

Concrete 5 in. thick reinforced with No. 8 A.R.C. Fabric for light to medium traffic for ordinary roads where the sub-grade has a safe bearing capacity of more than 15 cwts. per sq. ft.

Concrete 7 in. thick reinforced with No. 6 A.R.C. Fabric for medium to heavy traffic such as main roads and for medium traffic on a weak formation.

Concrete 8 in. thick reinforced with a layer of A.R.C. Fabric top and bottom for exceptionally heavy traffic, and for main roads on a bad formation.

Square mesh is also used in roadwork, and for this purpose the alternatives to Nos. 9, 8, and 6 are Nos. 655, 633 and 611, respectively. The longitudinal reinforcement has the advantage of providing twice as much resistance to transverse cracks, and twice as much strength along the edges where it is greatly needed.

The value of a road reinforcement depends on the yield point of the material, and A.R.C. Fabric having an average yield point of 70,000 lbs. per sq. in. is 75 per cent. greater in value than an equal weight of M.S. rod having a yield point of only 40,000 lbs. per sq. in.

A.R.C. Fabric in a road presents no obstacle to trench cutting, for although the wires are of high tensile strength, they may be easily cut with bolt cutters.

EXPANSION JOINTS

We suggest expansion joints should be spaced at not less than 120 ft. intervals, although past practice was to have more closely spaced joints, which spoil the riding qualities of the road and add to the difficulties of construction and maintenance. The present tendency is towards more widely spaced expansion joints with or without intermediate contraction joints of the top "dummy groove" type.

The expansion joints are filled with a non-extruding compressible material such as impregnated fibre-board, and

sealed at the top with a plastic filler to prevent access of water. Dowel bars are used across the expansion joints to assist in load transference. Each bar is treated for one-half its length to prevent bonding, either by painting and oiling or by an enclosing sheath, and then the oiled end fitted with a metal or cardboard cap giving a clearance space at the end of the bar equal to the width of the expansion joint. It is essential that each dowel bar be firmly held parallel to the surface of the pavement and at right angles to the joint during concreting. For this purpose, it is advisable to use a dowel bar assembly or holder.

CONSTRUCTION OF CONCRETE ROADS

The specifications for concrete for building purposes are not very suitable for road work, as greater care has to be directed to points such as the hardness of the concrete and its resistance to abrasion. On all major works, it is desirable to design the concrete mix scientifically according to the type and grading of the aggregates available. Trial mixes will indicate the most suitable proportions to give the best degree of workability with the lowest water content.

In Australia, Normal Portland cement is almost entirely used for road slabs, even where it is essential to open the road to traffic with as little delay as possible. In such a case, it is considered preferable to obtain the strength required by increasing the amount of Normal Portland cement rather than by using High Early strength cement, as concrete made with the latter cement is more susceptible to shrinkage cracking.

Careful consideration should be given to the selection of the aggregates with particular attention to their cleanliness.

SUB-GRADES AND SUB-BASES

Where the sub-grade consists of suitable granular material, the concrete slab may be placed directly on top without special treatment except for shaping and compaction, but for fine-grained soil, it is desirable to use a sub-base of a better type material under the slab.

In any case it is important to obtain uniform compaction with the greatest possible density.

Intense frost can do severe damage to all types of roads by causing local heaving, or it may produce a progressive expansion and softening of the sub-grade which will reduce its supporting capacity.

To prevent this damage, replacement of the susceptible material may be necessary, or alternatively the use of a cement stabilised base course which retards movement of water through the soil is an advantage, particularly on clay soil.

Sub-bases are usually constructed either of free draining granular materials which provide a drainage layer beneath the slab, or of well graded and stabilized materials, and in both cases their main function is to provide a foundation of uniform bearing capacity. The thickness of granular sub-base varies from 2 to 6 in., depending on the nature of the sub-grade, and materials such as ashes, gravel, or coarse sand are commonly used. Where a stabilised sub-base is used, some reduction in slab thickness can be made, but the reduction is as yet rather indeterminate and is the subject of current experiments.

A layer of waterproof building paper placed beneath the slab not only prevents leakage of cement paste, but by reducing the friction between the slab and sub-base or subgrade, considerably reduces the tensile stresses resulting from contraction of the concrete in cooler weather.

The following brief rules are recommended for all reinforced roads other than fully mechanised major constructions.

1. Roll in 3 in. of ashes on clay sub-soil, elsewhere lay the concrete direct on the prepared formation. It is important that the formation be thoroughly moist at the time of placing the concrete.

2. Aggregates must be hard, durable, and well graded, with particular care given to cleanliness.

3. Normally use one part Portland cement to two parts dry fine aggregate to four parts of coarse aggregate, the proportions measured by weight of dry materials.

4. Mixing water between 5 and 6 gallons per 94 lb. bag of cement, depending upon the amount of water in the aggregates and their characteristics. When mechanical vibration is used, this amount should be reduced.

5. Side forms must be correctly and firmly set as the evenness of the road depends upon the correct setting of these forms.

6. Maintain the correct cover on the bottom reinforcement, either by rolling $1\frac{1}{2}$ or 2 in. pipe along under the mesh as pouring progresses, or by small precast cement blocks. For top reinforcement, the concrete may be

"struck off" 1½ to 2 in. below the top surface immediately prior to placing the reinforcement, and then pouring continued within 15 minutes.

7. Compact the concrete thoroughly with a heavy tamper worked off the side forms, but preferably use mechanical vibration.

8. Work the concrete well against forms, and here again vibration is an advantage.

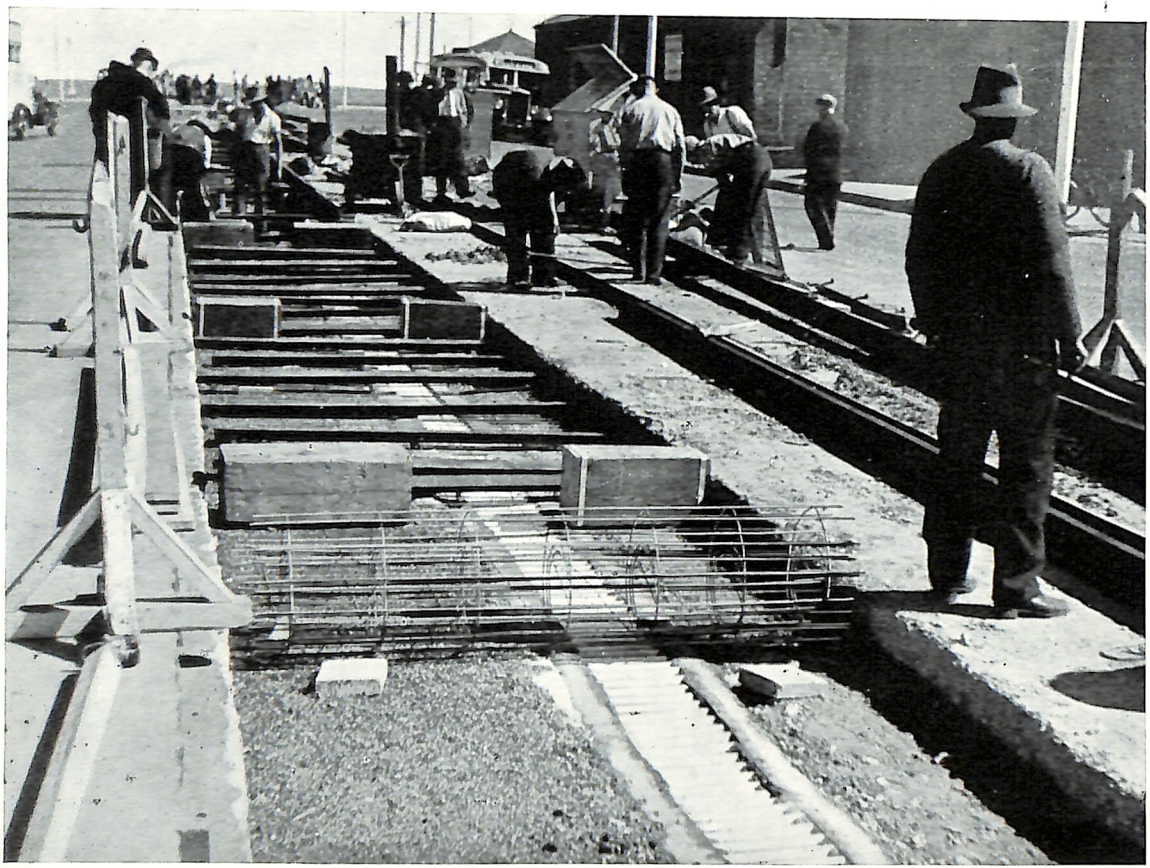
9. Finish with a canvas or rubber belt 8 to 12 in. wide, drawn with a combined transverse and longitudinal motion, or finishing may be carried out by machine.

10. It is suggested that permanent transverse expansion joints be formed at 100 to 120 ft. intervals, but in any case, at the end of each day's work.

11. Protect the concrete against rapid drying out by keeping the surface damp for at least two weeks. This may be done by covering with wet sand or waterproof paper.

12. Protect the concrete from frost during setting. Do not place concrete at temperatures below 36°F. on a falling thermometer.

13. Keep traffic off the road for at least 3 weeks after pouring, and longer if curing conditions are very unfavourable (assuming Normal Portland cement is used).



TRAM TRACK FOUNDATIONS

MELBOURNE

TYPES OF CONSTRUCTION

REINFORCED CONCRETE BUILDINGS

Reinforced concrete work is used in large buildings in the following principal ways:—

(a) Complete reinforced concrete frame building with monolithic reinforced concrete floors and walls.

(b) As above, except with brick or other type panel walls, or the outside framework completely encased in brick or stone.

(c) Reinforced concrete interior framing and floors, with external brick bearing walls.

(d) Structural steel frame with reinforced concrete floors.

(e) Reinforced concrete floors supported on brick bearing walls and structural steelwork.

Of these various types of buildings, for equal conditions, the complete reinforced concrete frame building provides the strongest construction, and is able to resist shock loads which were never contemplated during the design. Examples have occurred in overseas countries during the last war where buildings of this type have been struck by a heavy bomb, and the damage has been confined to local shattering of the floor and the blowing out of some wall panels. On the other hand, buildings carried on brick bearing walls have completely collapsed under attack from much lighter bombs. In Japan, the only buildings which reasonably withstood the atomic bombs were framed in reinforced concrete.

From the standpoint of resistance to shocks of all kinds, buildings other than light single or two-storey work should be framed, preferably in reinforced concrete. This lesson has already been learnt in those countries subject to earthquakes.

A complete frame building is composed of the following structural elements:—

(a) Foundations.

(b) Columns.

(c) Main beams and wall beams framing directly into the columns, and usually with secondary beams bearing on the main beams.

(d) Floor and roof slabs.

(e) Walls.

Although these items are enumerated separately, they are formed in one monolithic whole—except when brick or similar panel walls are used—since construction is as far as practicable continuous.

Where stoppages do occur, precautions are taken to bond the later work to that already cast.

A frame building may be "beamless", known as the "flat slab" or "mushroom" type. With this construction, the principal elements are (a) foundations; (b) columns flared out at the tops to receive (d) the floor slabs directly or a drop panel supporting the floor slab, and (e) walls. Item (c) is omitted as beams are unnecessary, except where wall spandrel beams and trimming beams around large internal openings are required.

The advantages of flat slab construction are:—

(1) Greater load carrying capacity for a given amount of concrete and steel, and decreased danger of collapse under overload, due to the tendency of the entire floor to act together.

(2) Formwork for floor slabs is simplified and cheaper than for beam and slab construction.

(3) Absence of beams simplifies the installation of automatic sprinklers, heating and lighting outlets, and permits better ventilation.

(4) They can be designed without wall spandrel beams projecting below the ceiling line, thus allowing the windows to extend to the ceiling and resulting in better natural as well as artificial lighting. The absence of deep beams and girders also removes the obstruction to the passage of light within the building.

(5) Greater fire resisting qualities, owing to the fact that the ceiling offers no sharp edges or corners as in beam construction, which spall off and weaken the floor.

(6) A considerable saving in storey height and total height of a building can be effected.

The system is only suitable for buildings where

(a) The slab is continuous for at least 3 panels in each direction.

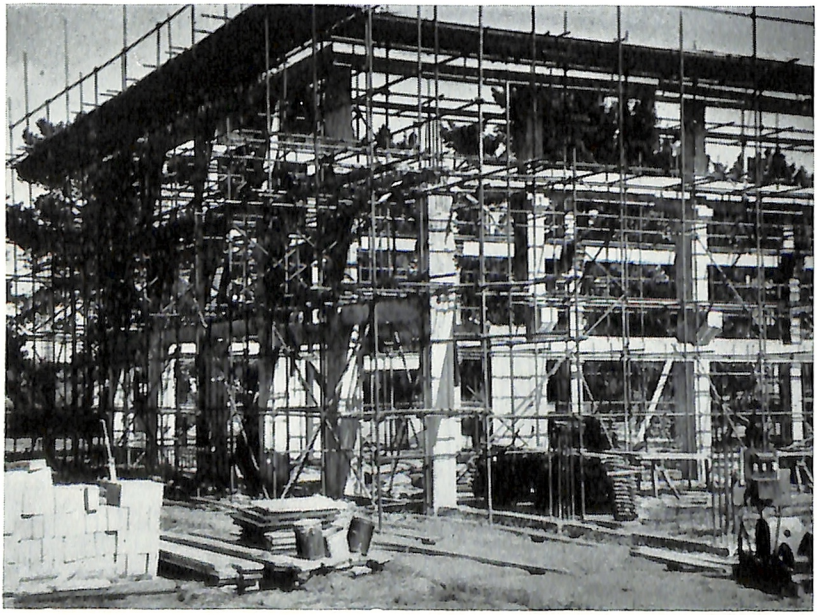
(b) The ratio of length to width of panel is less than 1.33.

(c) Successive span lengths in each direction do not differ by more than 20 per cent. of the shorter span.

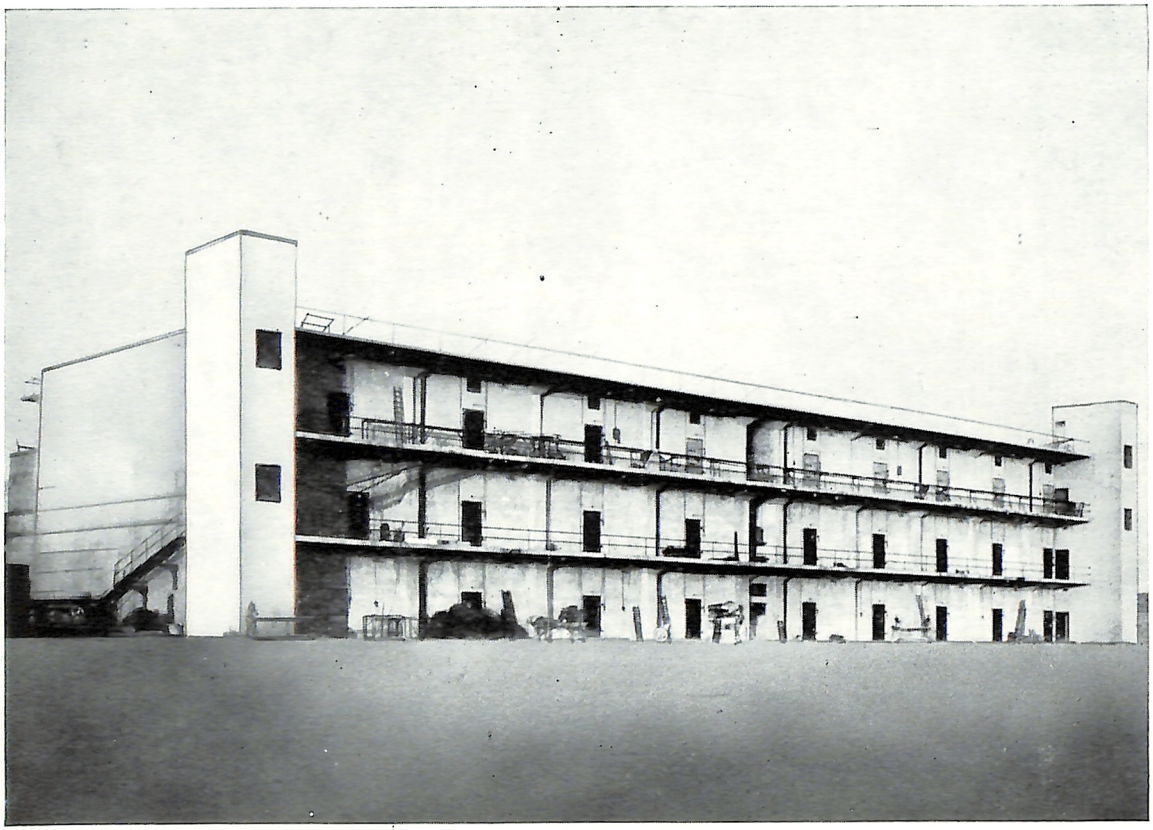
(d) The live load should be of approximately a uniformly distributed nature.

Due to the rather empirical nature of the design formulae and the various modifying factors which can enter into the problem, it is recommended that the design of this type of job be entrusted only to an engineer experienced with such construction.

For blocks of flats where rooms are relatively small and columns take up valuable space, reinforced concrete box



REINFORCED CONCRETE FRAME, MILL BUILDING **DANDENONG**



COOL STORES FLAT SLAB CONSTRUCTION SHEPPARTON

frame construction, i.e. reinforced concrete cross walls with solid slab floors and roof — is worthy of consideration. This method has been used overseas for some large projects of this nature.

In this type of construction, internal reinforced concrete walls act as load bearing structural units, taking the place of the conventional columns and beams. In domestic structures, it is often difficult to make the position of frame members coincide with that of the internal partitions, and the projection of beams and columns into rooms is usually undesirable.

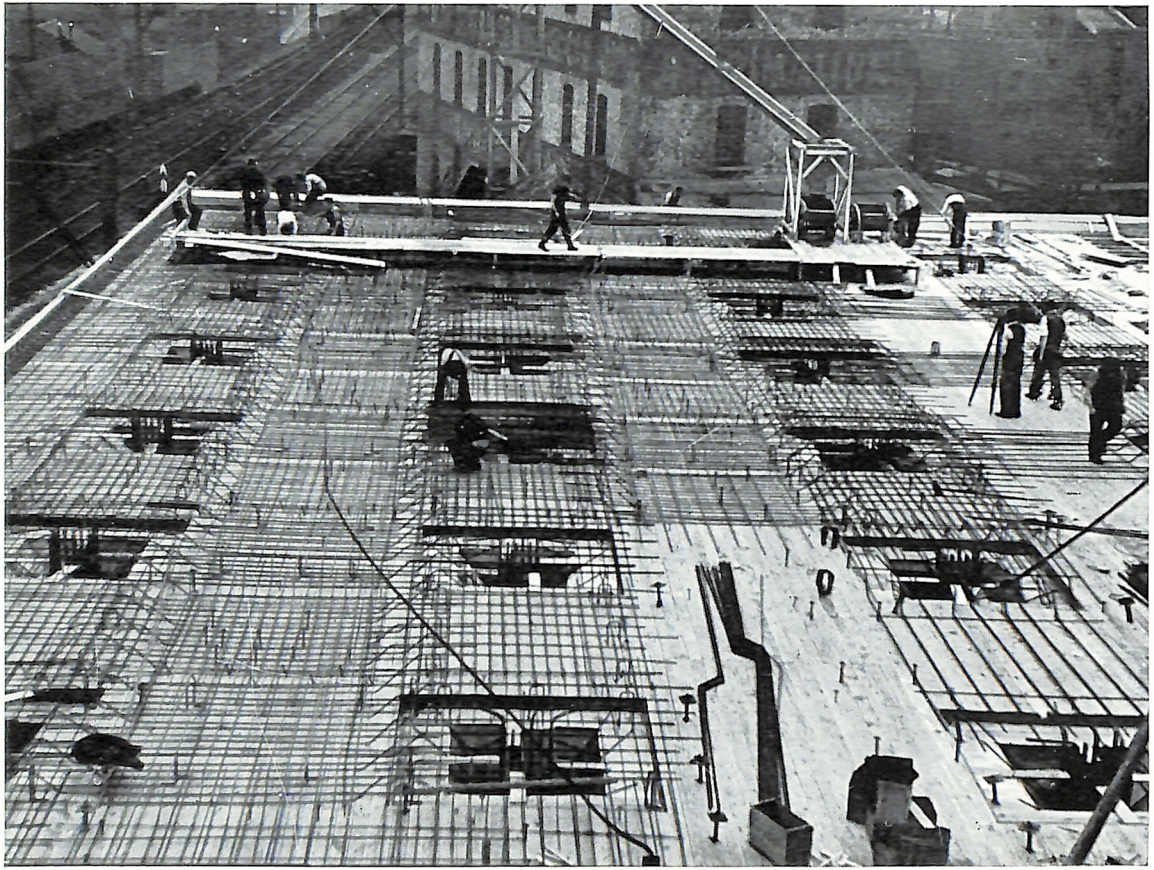
Advantages of the system are the absence of these members, and that, with the exception of the terminating concrete walls at each end of the structure, any type of infilling can be used for the external wall panels.

FACTORIES AND WAREHOUSES

Many multi-storied factories and warehouses are now constructed as framed buildings, using reinforced concrete as the structural element for reasons of durability and high fire resistance, compared with older forms of brick and timber construction.

Structural steel is the main alternative material, but if unprotected, has the disadvantage of requiring regular painting and maintenance. Most building regulations require the steel work to be protected and made fire resistant by encasing in concrete suitably reinforced, but under these conditions the cost compares unfavourably with reinforced concrete. In addition, the quantity of steel used may be three times as great as the amount of steel in a similar reinforced concrete building.

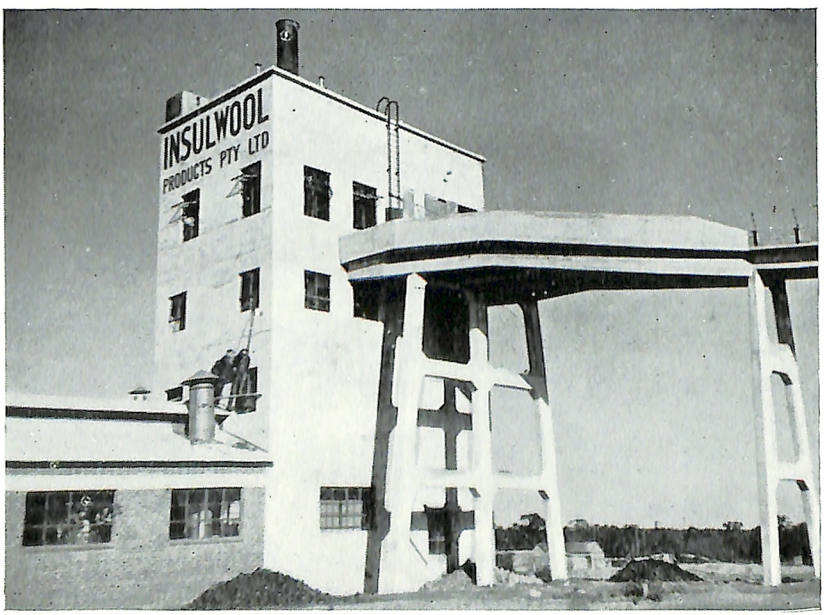
Generally, these buildings are framed with columns, beams and slabs, but the flat slab or "mushroom" construction is increasing in popularity. Many large cool stores and other structures have been designed by us using this system, and have given excellent service. This type of construction is suitable and economical for buildings more than 2 bays wide in either direction, with large areas of floors unbroken by openings, and carrying live loads more than 100 lbs. per square foot. Where the loads to be carried are relatively light and the spans of varying lengths, as in hotels, office buildings and similar types, it will be found more economical to use beam and slab construction.



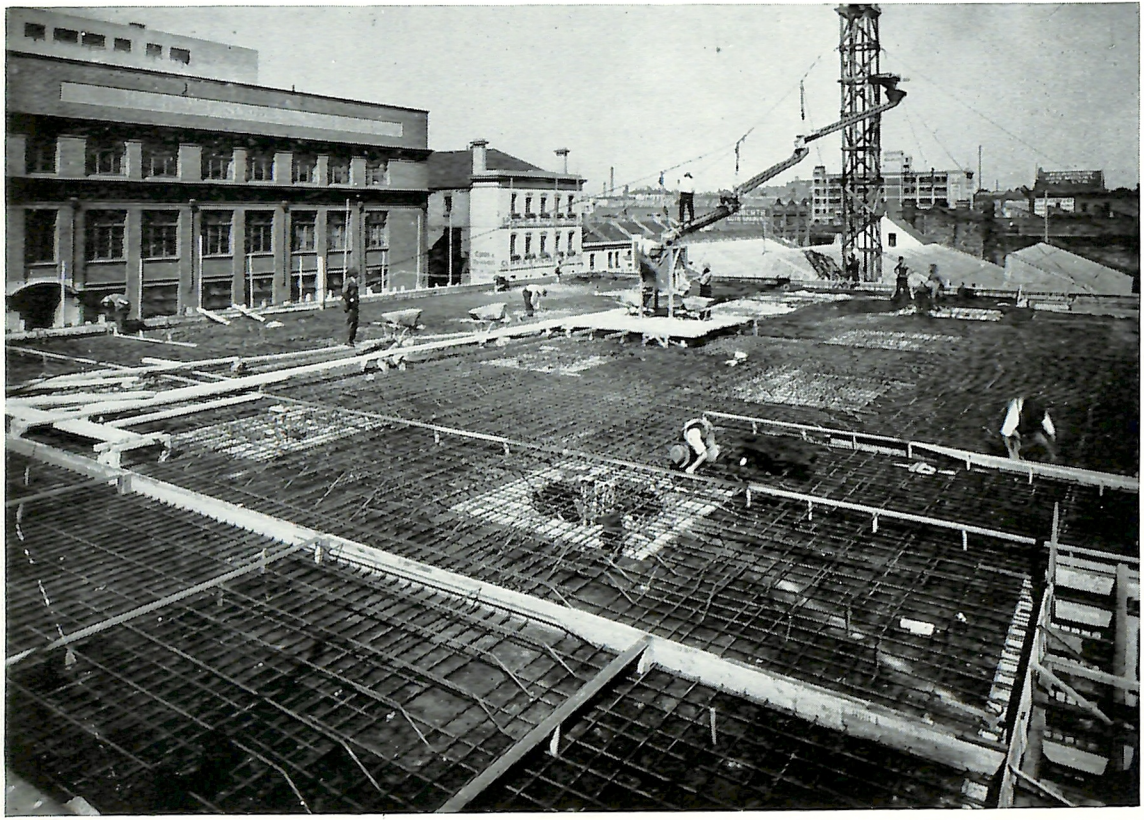
FLAT SLAB FLOOR TO COOL STORES.

SHEPPARTON

In the design of industrial buildings, collaboration between the Architect and Engineer is desirable from the commencement, as the question of column spacings, floor thickness, and headroom may influence the cost of the building to a great extent. Generally, the closer the column spacing and the deeper the beams, the lower the cost. The approximate arrangements of pipes and other services should be known at the outset, so that the building can be designed around them or suggestions made to simplify construction. For factories and warehouses constructed of structural steel framing, foundations and floors are usually of reinforced concrete, preferably reinforced with A.R.C. Fabric.

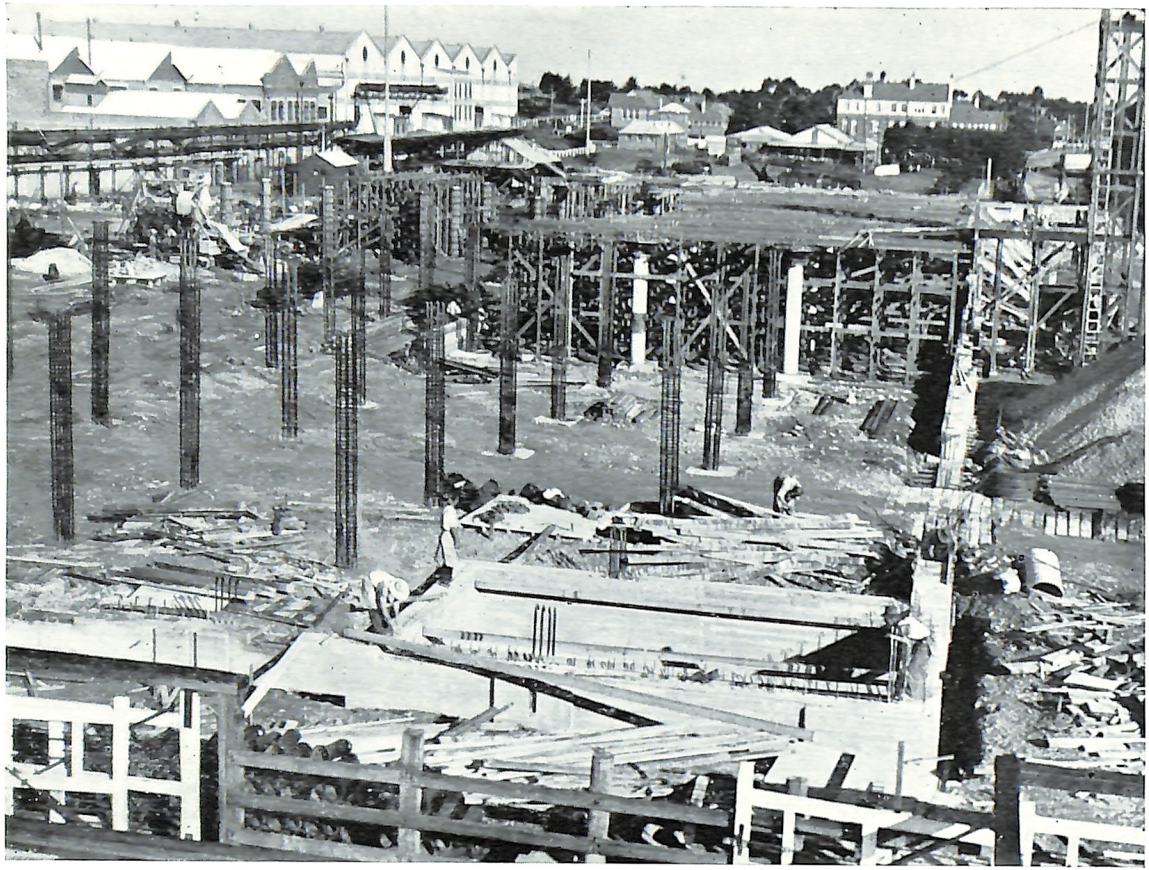


FACTORY AND OVERHEAD ROADWAY. MELBOURNE



FLAT SLAB FLOOR TO GARAGE.

MELBOURNE



MUNICIPAL ABATTOIRS HOMEBUSH, N.S.W.

FLAT SLAB FLOORS REINFORCED WITH A.R.C. FABRIC.

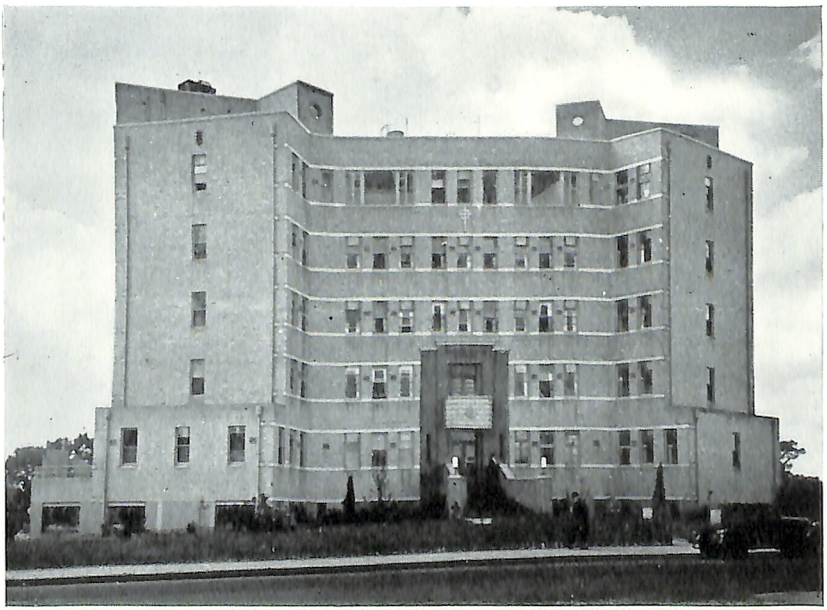
PUBLIC BUILDINGS

These include halls, theatres, hospitals and schools. These buildings are often framed in reinforced concrete and have reinforced concrete floors, and sometimes the structure is faced with brick or stone work.

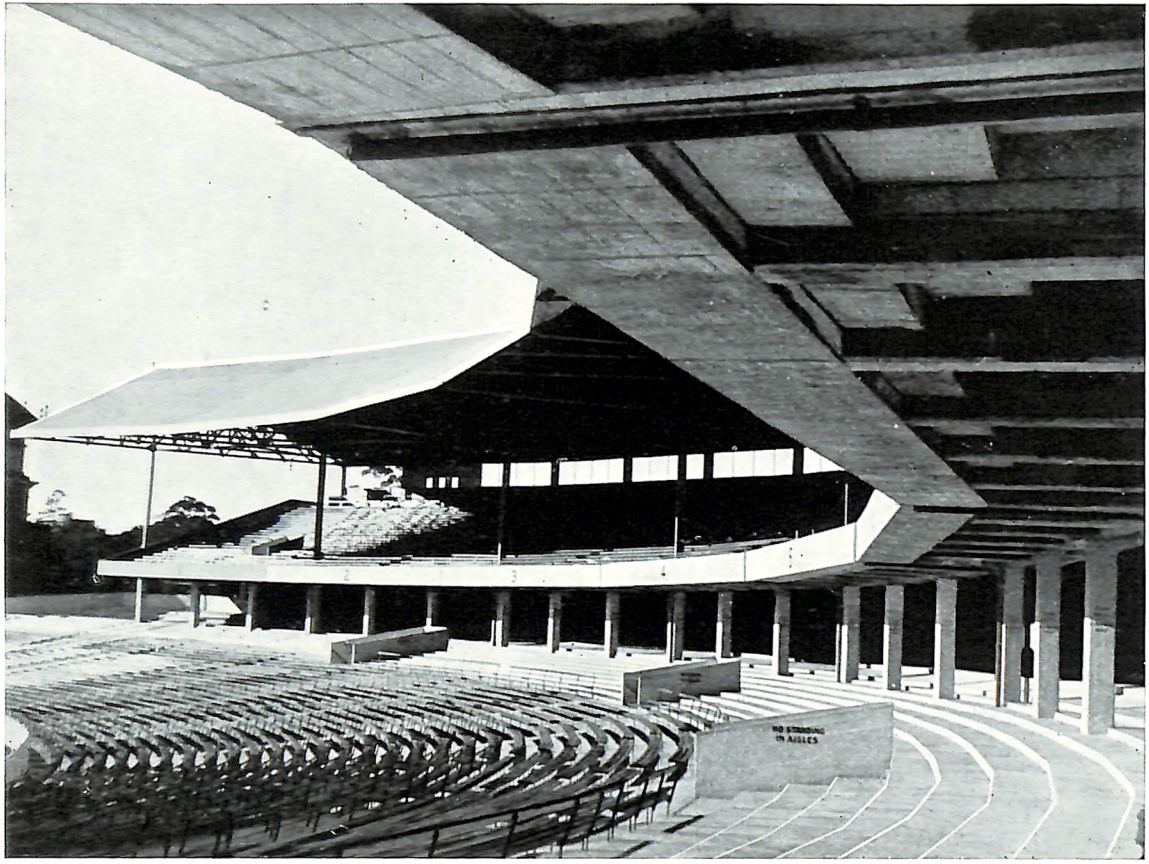
Hollow-block construction is widely used in hospital and school buildings because it enables long spans to be covered with a flat ceiling and few beams. It also has the advantage of additional soundproofing and thermal qualities, whilst pipes and services can be placed between the floor and ceiling.

Reinforced concrete enables the adoption of cantilever balconies and corridors, enhancing the appearance and convenience of the building.

Sometimes the walls of the buildings are of the brick-bearing type with floors and roof only of reinforced concrete. Wartime experiences overseas have, however, shown the importance of framing such buildings in reinforced concrete to limit the area of destruction caused by one bomb.



HOSPITAL **MELBOURNE**



GRANDSTAND

MELBOURNE

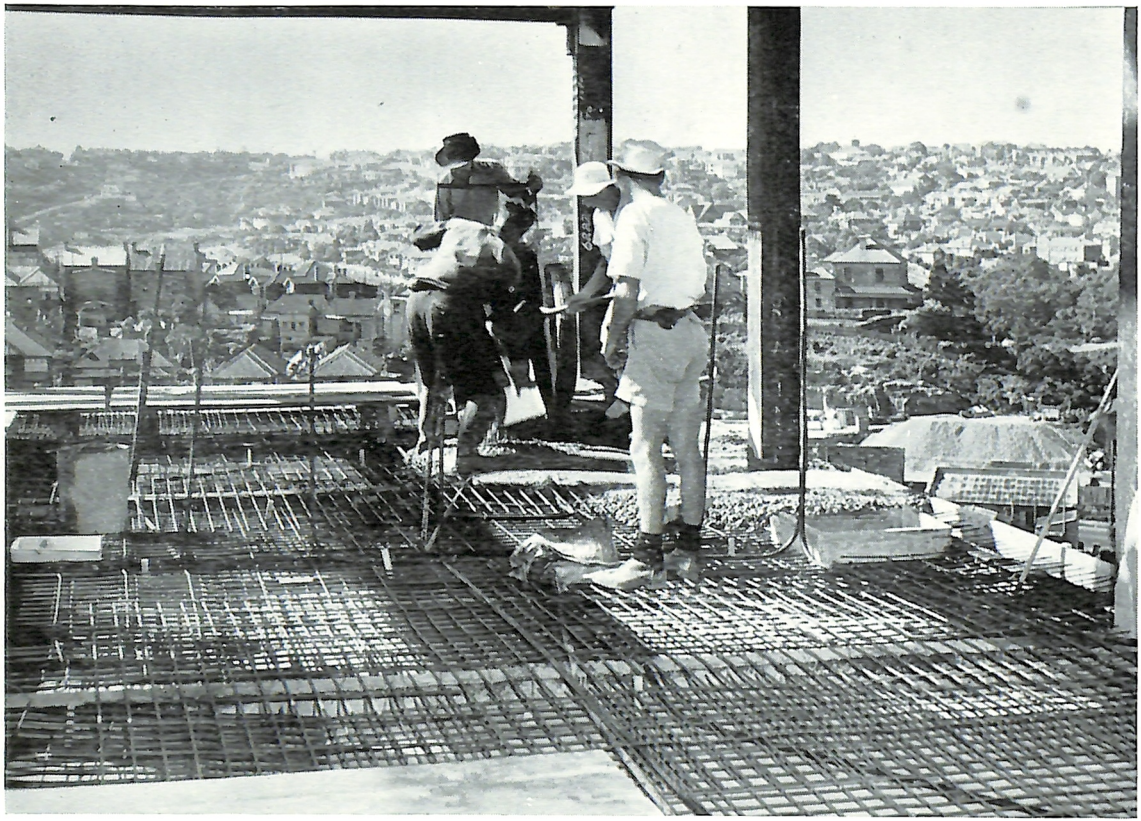
FLATS, HOTELS, OFFICE BUILDINGS, ETC.

For buildings of this type not exceeding three or four storeys in height, brick bearing walls will probably prove more economical than complete reinforced concrete frame construction. Above this height, frame construction is normally used. The walls then become infilling or panel walls, and need be only 9 inches or 11 inches thickness if constructed of normal brick work.

Reinforced concrete will, in most cases, prove cheaper than structural steel for the frame members.

Reinforced concrete is also used extensively for such structures as theatres and grandstands, as the high degree of fire resistance of this material is especially important in buildings where a large number of people are accommodated.

FLATS **MELBOURNE**



MULTI-STOREY FLATS

SYDNEY

HOTEL ALBURY

CHURCHES AND SIMILAR STRUCTURES

Reinforced concrete is being used to an increasing extent in the construction of such buildings: although the walls are usually of brick or stone, reinforced concrete is frequently utilised in the roof construction. Often the arched roof members, with supporting columns, are of concrete, although this imitation of traditional form is being displaced by a type of architecture more expressive of reinforced concrete.

It is suggested that structures quite unlike the old cathedrals, but perhaps equally inspiring, may be built in reinforced concrete if its use is guided by technical knowledge and pride in good workmanship.

CHAPEL CROYDON

SPIRAL STAIR MELBOURNE

SILOS AND BINS

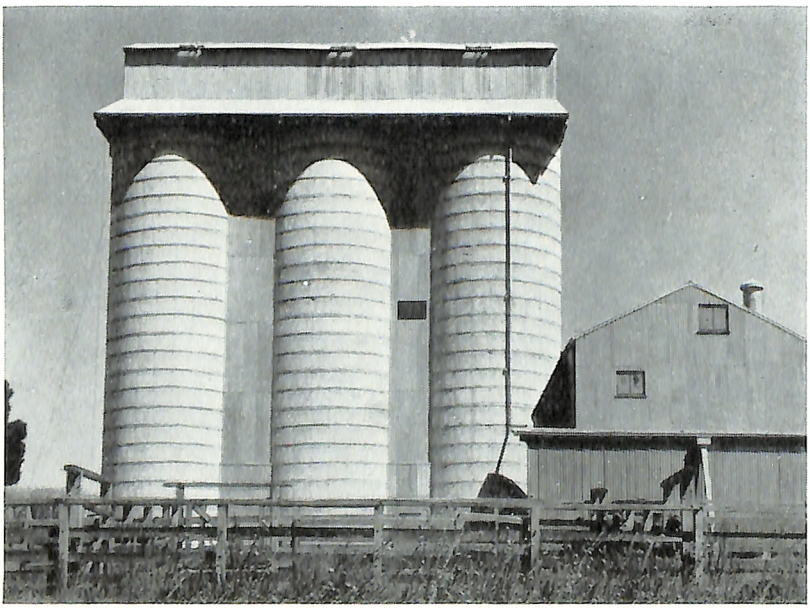
Reinforced concrete is extensively used for the construction of silos for the storage of grain and silage, due to its high fire resistance, durability, and the resistance it affords against vermin.

For large silos, moving formwork is generally used, thereby permitting of rapid construction. It is advantageous for the designer to have a working knowledge of this formwork, as the requirements of construction may be of at least equal importance as academic considerations. It is common practice to use the same thickness of wall from top to bottom.

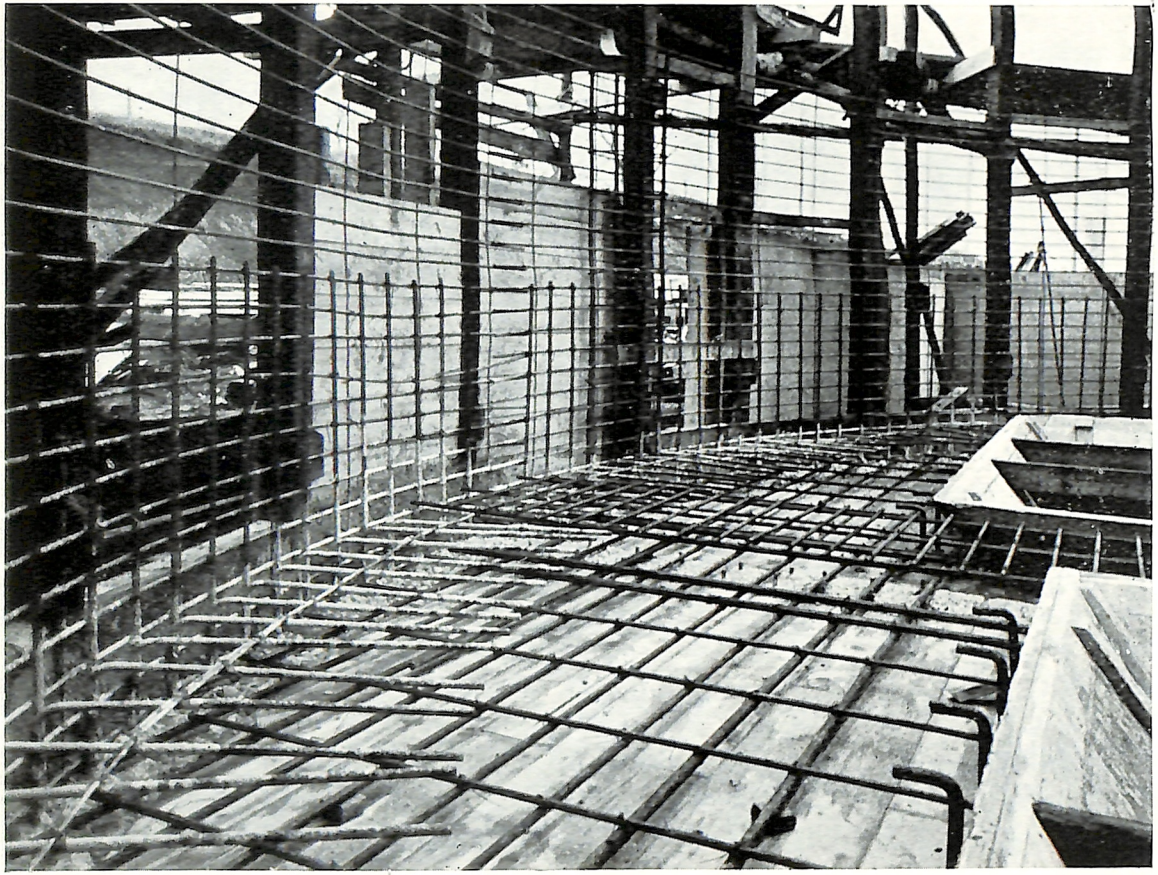
Numerous silos have been constructed to the designs of this company, and many of them are reinforced with A.R.C. Fabrics.

Sometimes, steel bins are constructed for storage of materials such as cement, coal, etc., but with materials such as coal and coke, corrosion is rapid. The useful life of a reinforced concrete bunker is much longer than that of a timber or steel structure, and this life can be further prolonged by careful detailing.

By thus reducing the tendency to cracking, the concrete does not deteriorate so quickly under service conditions due to abrasion. If proper attention is given to obtaining a hard,



SILOS **KYNETON**



CIRCULAR STORAGE BIN

MELBOURNE

dense concrete, lining with steel is not necessary, except perhaps for coke or where coal or stone is dropped from a considerable height.

RETAINING WALLS

Until the introduction of reinforced concrete, all retaining walls were of the gravity type, i.e. their stability depended upon their own weight. Under the usual conditions of earth pressure, such walls would be very thick at the base, often with a thickness from $\frac{1}{3}$ to $\frac{1}{2}$ the height.

The reinforced concrete wall consists of a thin retaining slab with or without counterforts, and a base slab, preferably projecting into the retained earth. The weight of this earth is thus utilized in stabilising the wall against overturning.

For normal conditions, brick work, stone or mass concrete is probably cheaper for low walls up to about 6 ft. high. Above this height, reinforced concrete has outstanding advantages.

The cantilever type, consisting of a vertical cantilever wall monolithic with a base slab, is used for heights up to about 15 ft. or more. Above this height or for high pressures, the counterfort wall effects a saving in materials, although, due to its greater constructional simplicity, the cantilever wall is found to be more economical up to a height of about 18 ft.

In the counterfort type, the wall slab spans horizontally between vertical counterforts or buttresses, although for very high walls the wall slab may span vertically between horizontal beams which re-act on the vertical counterforts.

A retaining wall must be designed to resist the earth pressure without overturning, sliding, or overloading the ground at the toe. It is easy to adapt reinforced concrete to meet adverse conditions in these cases; for instance, if the ground is wet clay, a projecting nib may be formed below the footing, which makes sliding impossible, also the toe of the foundation may be carried out as far as necessary to reduce the ground pressure and to give the proper measure of stability. Any surcharge due to loading on the retained earth, such as from roadways, adjoining buildings, etc., must be allowed for in calculating the pressure on the wall.

Retaining walls should have additional distribution reinforcement on the exposed face to provide for temperature and shrinkage stresses if the wall exceeds about 8 inches in thickness. In any case, expansion joints should be provided at intervals not exceeding 60 ft. Owing to the danger of water

collecting behind the wall, weep holes should be provided through the wall near the bottom, and broken stone or other coarse material placed around the weep holes at the back of the wall.

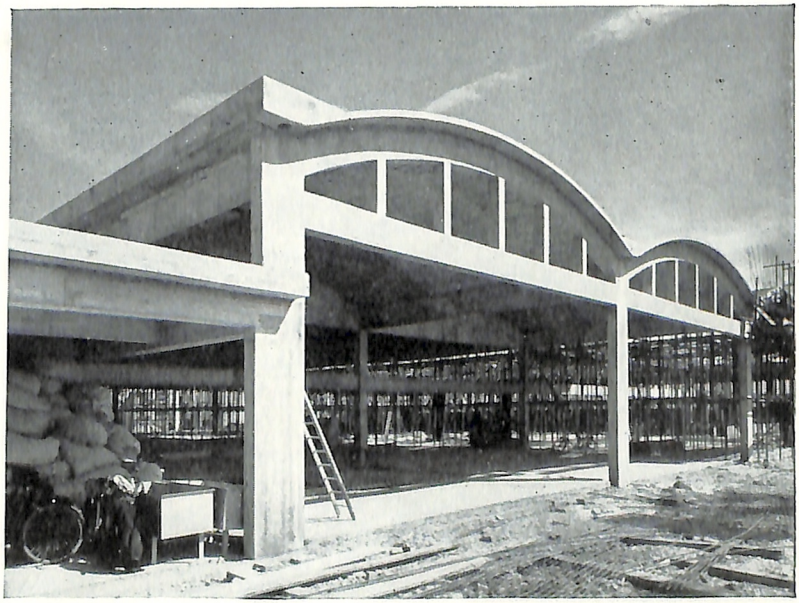
CONCRETE SHELL AND BARREL ROOFS

During recent years, great developments have taken place in overseas countries with this form of roof construction. The system was largely used in the United States during the last war to effect economy in the use of steel, and is not unduly difficult to construct, especially if designed to permit the use of standardized forms.

The two types are the curved shell or barrel vaulting, and the hip plate which consists of thin concrete slabs forming an inverted trough.

Shell construction makes it possible to roof over large areas without internal supporting columns, an ideal form of construction for garages, halls, and similar structures.

The appearance of the shell concrete roof is in keeping with the modern trend in architecture.



BARREL VAULT ROOF **GRAYS, ENGLAND**

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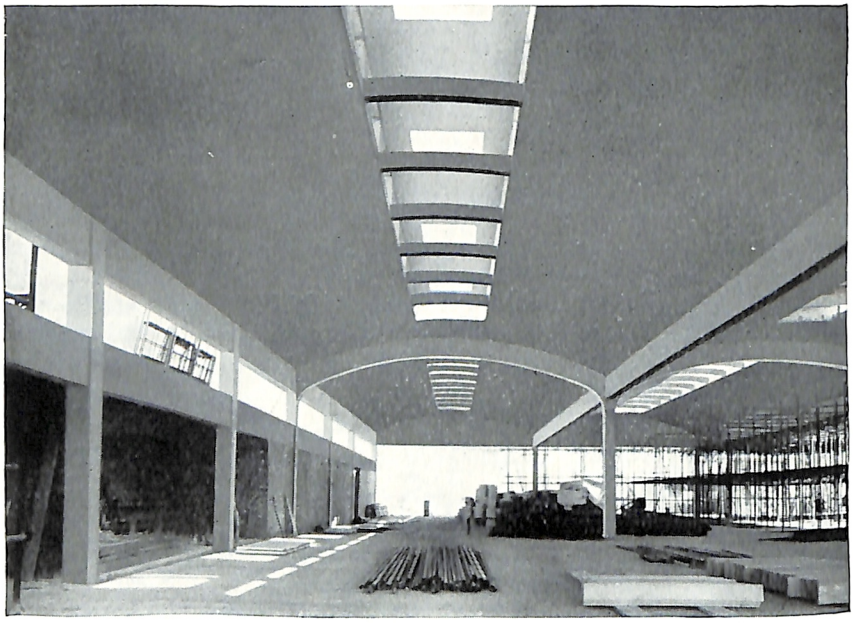

BARREL VAULT ROOF GRAYS, ENGLAND

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HIP PLATE ROOF BRISTOL, ENGLAND

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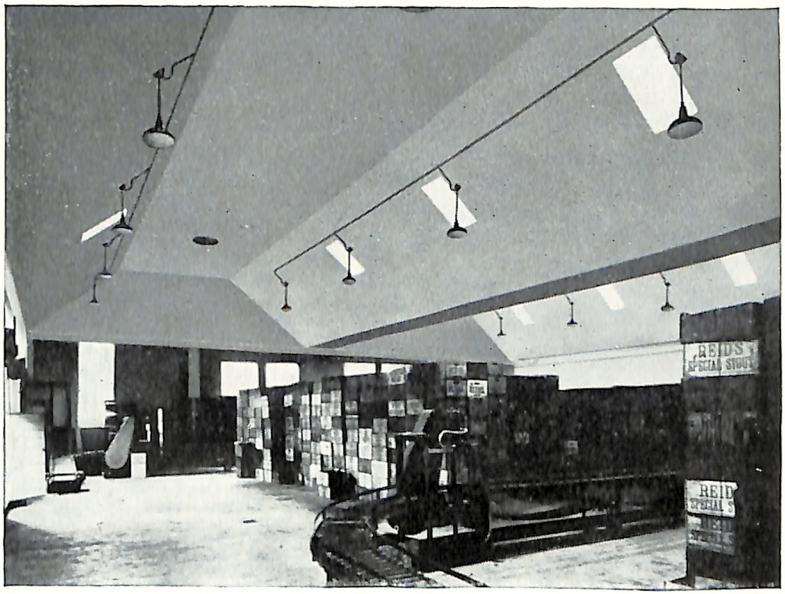

HIP PLATE ROOF **ALTON**

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TANKS AND WATER TOWERS

Many tanks for the storage of liquids and other industrial purposes, including sewage treatment works, gas holder tanks, etc., are best constructed in reinforced concrete. They may be circular or rectangular in shape, either roofed or uncovered, and can be constructed above or below the ground as required.

Where liquids injurious to concrete are to be stored, some form of protective lining may be necessary, although in the case of wine and beer tanks, it has been found satisfactory to apply a wax coating to the inside concrete surfaces. This coating does not affect the flavour, colour, or stability of the contents. If the tank has been rendered, the surface should not be unduly heated when applying the wax as the rendering may flake off.

Water towers may be supported on columns properly braced, or preferably on a reinforced concrete shaft, with the tank partially cantilevered out at the top. Small tanks usually have flat bottoms, but for large tanks a domed floor may be

more economical, as although the cost of the shuttering is considerably greater, considerable savings in materials are effected.

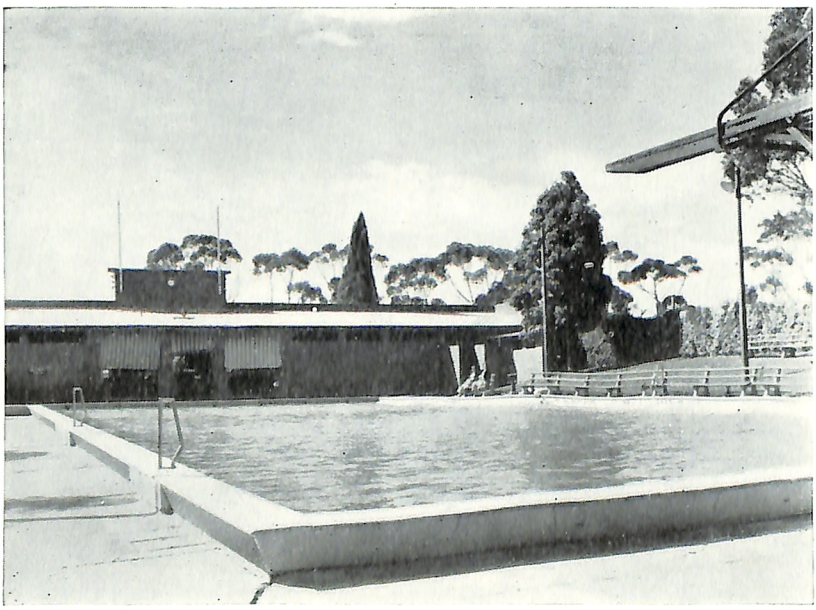
All tanks require particular care in the proportioning, placing, and curing of the concrete, and proper attention must be given to all construction joints. If these precautions are observed, a special waterproof lining or integral waterproofing compound will not be necessary.

Further information regarding watertightness and construction joints is given on pages 92 and 93, respectively.

SWIMMING POOLS

Practically all modern swimming pools are constructed of reinforced concrete, and we have supplied designs and reinforcements for a very large number.

Some of these pools were constructed more than twenty years ago, and are still giving good service. Striking effects



MUNICIPAL SWIMMING POOL BOX HILL

can be achieved by constructing the diving stages in reinforced concrete, and the material is also readily adaptable to the production of such features as underwater lighting and coloured tiling. Although the scum gutter can be moulded in the top of the concrete wall, it is preferable to use a special tiled gutter section for simplification of construction and better appearance.

Pools should be kept full of water when not in use during the winter, as cracking may occur if they are empty for any length of time.

BRIDGES

Bridge construction offers a wide field for the reinforced concrete engineer, and it is noteworthy that some of the earliest reinforced concrete structures were bridges. The various advantages which make reinforced concrete so suitable in many branches of construction are combined in bridge construction, and its qualities of durability, economy, strength, resistance to vibration, low maintenance cost and good appearance, have resulted in numerous bridges being constructed in reinforced concrete in recent years. The adaptability of the material to any situation and to any architectural treatment has resulted in many beautiful bridge structures in favourable contrast to some of the ugly iron and steel structures erected in the past.

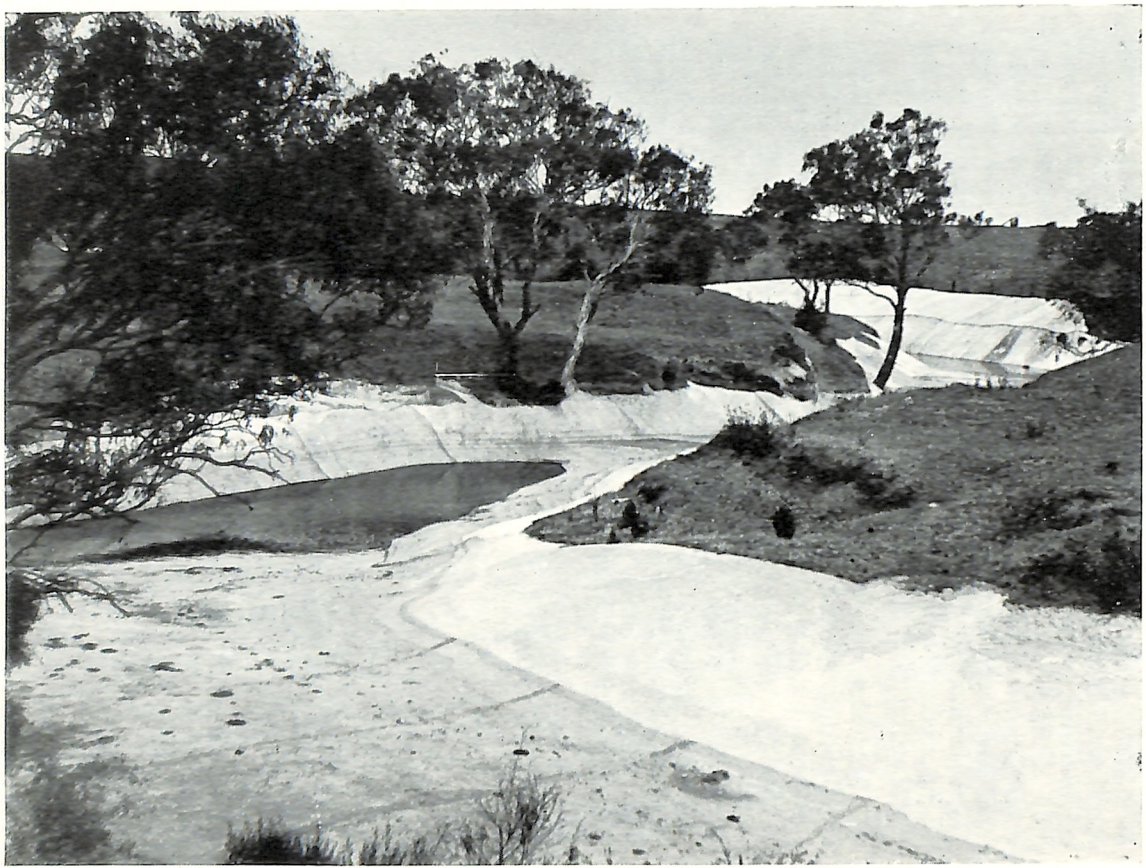
The two principle types are arches and girder bridges, the selection of type largely depending on the span, the nature of the foundations, and the head room required. The girder type of bridge is generally used for small spans and for longer spans where the head room is limited, but where the situation permits, arch construction is more suitable and economical for large bridges. Spans of more than 800 feet have been successfully accomplished. Arch bridges may have either open or closed spandrels, and the arch itself may consist either of a slab, reinforced concrete barrel, or individual ribs. Many bridges are a combination of the two types, in which the structure acts as a continuous rigid frame.

Although the superstructure of bridges may result in more spectacular engineering, it is in the foundations and piers that the most difficult problems usually arise. The arch bridge should not be used excepting when a hard gravel or rock foundation can be secured near the surface. In other circumstances, the girder bridge or the rigid frame type, if necessary carried on piles, should be adopted.

SWAN ST. BRIDGE

MELBOURNE

(Reproduced by courtesy of the Country Roads Board of Vict.)



CONCRETE LINING FOR RIVER EROSION WORKS

VICTORIA

PRECAST CONSTRUCTION

Precast construction has advantages over in-situ work in certain circumstances, and it is sometimes advantageous to construct members of a structure separately and assemble them later into a completed framework. It is often easier to precast members where concrete placing or the provision of supports for formwork may be difficult. Also, where unskilled labour and only a minimum of supervision is available, precasting may enable manufacture to be localised and carried out under more convenient conditions, with protection from inclement weather. Other favourable circumstances would be shortage of formwork, or where a repetition of similar members makes it actually more economical to precast.

The design of precast structures introduces special problems, chiefly in the handling and joining together of the various members, but it is usually possible to devise satisfactory ways of dealing with these. Consideration must be given to the weights of the members relative to the capacity of available lifting tackle, and the lifting points should be approved by the engineer. Where the reinforcement is not disposed symmetrically as in lintels or slabs, the members should be marked when they are cast to show which face is to be placed uppermost in the finished work.

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